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OF
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JOURNAL OF THE
BOSTON SOCIETY OF CIVIL ENGINEERS

Volume XIX MARCH, 1932 Number 3

GEORGE WASHINGTON, ENGINEER

By Edward Grossman *

I

One side of George Washington's career has been sadly neglected by his biographers. Our first President was professionally, and also by aptitude, an engineer. The neglect of this phase of his interesting life is due not so much to lack of interest as to ignorance. Of the five hundred (more or less) biographies of Washington, not one has been written by an author capable of appreciating the significance of his early career and able to reconcile it with his later work.

George Washington wrote voluminously. He left us diaries, copies of letters, journals and ledgers written during his lifetime. Professor Jared Sparks, who first collected Washington's writings (1837), attached little importance to his early journals and diaries. His lead was followed by the later biographers. They did attach importance to his "godlike calm" in the face of disorder, and to his extreme probity. These were the outstanding traits of his character. These were due, of course, to a habit of clear thinking and ability to be honest with one's self. And perhaps his attitude of mind had something to do with it. He was primarily an engineer with a thorough grasp of essentials. Side issues did not matter. This trait made him see political issues in a broad and impersonal way — not a popularizing trait, of course, but conducive to the benefit of the country as a whole. Thus, when the French Revolution broke out, and the notorious "Citizen" Genêt came over here to enlist sympathy, President Washington was almost the only one who did not lose his head. Nearly all his countrymen were clamoring to "pay our debt to France" and help her fight all Europe. The President alone saw the disadvantage of such a course and had Genêt recalled.

---

* Engineer, 88 Tremont Street, Boston, Mass.

Washington alone remembered that it was the French King who, because of hatred for England, helped the Americans. The French people had no more to do with the desire to help the Americans than the Hessians, who were hired out by their masters to fight the colonies.

He was also a great military strategist. If it were not for him we would not be American citizens. The study of this phase of his career is productive of material enough to fill two books. We will not dwell upon it, except to state that he conducted the Revolutionary War as a problem in engineering. Certain "key battles" had to be won. In these he was victorious. The British won, time after time, sometimes seriously crippling the American army, yet Washington was victor, because his engineering sense taught him to pick only essentials. The British commanders did not have that attitude of mind and lost the war for their King, although they won more battles for him.

He was the first agricultural engineer in the country. He designed and built his own buildings, devised agricultural implements, and conducted an experiment station.

He was the pre-eminent land developer of his time, forever trying to develop the western part of the country, forming development companies, improving communications and settling people on the land.

All that will, however, be told in its turn.

II

George Washington was born on February 22 (new style), 1732, in Westmoreland County, Virginia. His father was Augustine Washington, and his mother Mary (Ball) Washington, who was Augustine's second wife. George was the eldest son of this marriage. Not long after George's birth the family moved to Stafford County on the east side of the Rappahannock River opposite Fredericksburg. There Mr. Washington died at the age of forty-nine on April 12, 1743. Mr. Washington had been a thrifty planter and left his family in comfortable circumstances.

To each of his children he bequeathed an estate ranging in size from 2,500 acres, which was Lawrence's portion (he was the eldest), to the 600 or 700 acre tracts left for the younger boys. The mother was left in full charge until the respective heirs came of age.

When George was of proper age he was sent to school. In those days schools were kept for the purpose of teaching only the essentials. The real education was obtained usually in England at public schools and universities. The schools in Virginia at the time were kept by itinerant schoolmasters, parsons and the like.

George's first teacher was a Mr. Hobby, a former indentured servant and tenant on the Washington estates. Besides his occupations of sexton and occasional farmer, Mr. Hobby was also a schoolmaster, but he could not teach George very much. The latter was then sent to Mr. Williams's school, where he received a severely practical drilling in the execution of business forms, a smattering of miscellaneous education, and a great deal of mathematics. Of that Mr. Williams gave as much as the pupil desired.

Although George was a fairly apt pupil in the ordinary course of English and business forms, his greatest delights began when Mr. Williams led him through the mazes of geometry, trigonometry and surveying. He actually loved mathematics, and the more his teacher gave him, the more he desired.

The textbook used by Mr. Williams was the then popular *vade mecum*.

THE
YOUNG MAN'S COMPANION
OR
ARITHMETICK MADE EASY
with

Plain Directions for a Young Man to Read and Write true English, with Copies in Verse for a Writing School, Indicting of Letters to Friends, Forms for making Bills, Bonds, Releases, Wills, Ec.

LIKEWISE

Easy Rules for the Measuring of Board and Timber by the Carpenter's Plain-Rule, and by Fractions; with Tables for such as have not learned Arithmetick; And to compute the Charge of Building a House or any Part thereof.

Also Directions for Measuring, Guaging, and Plotting of land by Gunter's Chain; and taking heights and distances by the Quadrant and Triangle. The use of Gunter's Line in Measuring Globes, Bullets, Walls, Cones, Spire Steeples, and Barrels. With the Art of Dialling and Colouring of Work within and without doors. Directions for Dying of Stuff. Ec.

Together with a Map of the Globe of the Earth and Water, and Copernicus's Description of the Visible World. Also a Map of England; and to know which are Cities and their Distance from London.

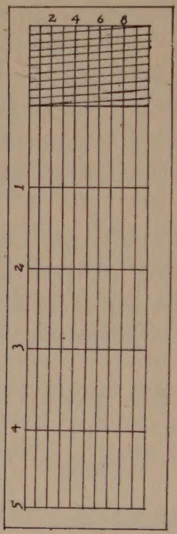
Choice Monthly Observations for Gardening, Planting, Grafting, Inoculating Fruit Trees, and the best Time to Prune Them; and the making Wine of Fruit; With experienced Medicines for the Poor.

An Account of Curiosities in London and Westminster.

Written by W. Mather in a plain and easy Stile that a young Man may attain the same without a Tutor.

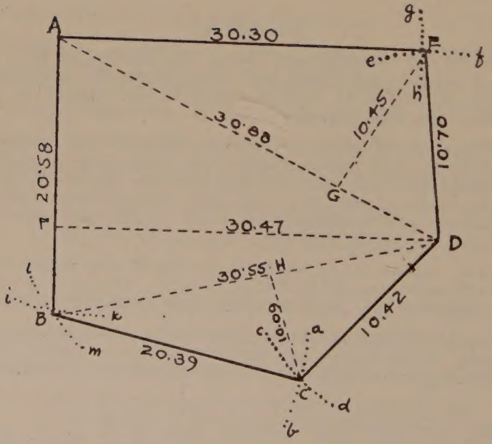
The Thirteenth Edition; with many Additions and Alteration, especially of the Arithmetick, to the Modern Method.

London: Printed for S. Clarke, the corner of Exchange Alley, next Birchin Lane 1727.



DIAGONAL SCALE

FIG. 1



"To Meaſure a Cloſe"

FIG. 2

This book George studied over and over again. From it he completed his education in "Arithmetick," and learned geometry, surveying, farming, medicine and all the other good things promised on the title-page. From the lessons learned in its pages he earned his living during his professional career as a surveyor. He learned how to be methodical and precise, and to think clearly.

The following extracts from the twenty-fourth (1750) edition of this work will no doubt be of interest:

Of Surveying, or measuring Land (p. 299)

NOTE, that 16 Feet and an half make a Pole or Perch; 160 Square Poles, or 4 Roods, make an Acre of Land; 40 Poles make a Furlong, 8 Furlongs, or 17 yards, make a Mile.

Land is generally measured by a Chain of 4 equal Parts, or Links, 25 of which are a just Pole, or Perch; consequently, 10 square Chains, or 100,000 Links, make an Acre of Land. But though this Chain, called Gunter's Chain, from it's Inventor, be commonly used, yet Land may be measured by a Cart-Rope, or a common Pole, 16 Feet and an Half in Length.

How to measure Land by Gunter's Chain

We have already observed that this Chain is 4 Poles in Length, or 22 Yards, which is 66 Feet, or 792 Inches; it is divided into 100 Links, at every 10 Links is a Brass Ring, for the more ready counting it in Measuring, so that it is no matter which End goes foremost; and he who draws it should carry in his Hand 10 small Sticks, to stick in the Earth at every Chain's Length, and he who follows the Chain to gather up the Sticks.

A Description of the Diagonal Scale, very useful in plotting, &c. Land.

[See Fig. 1.]

This Scale consists of 11 parallel Lines, equi-distant from one another, so as to include 10 equal Spaces, which are cut by perpendicular Lines, dividing the Scale into equal Parts numbered 1, 2, 3, 4, 5. One of these Divisions, viz. the last on the Right hand, is subdivided by diagonal Lines; so that if one of the Large Divisions represent Chains, a Line may be measured to a single Link, one of the large Divisions being subdivided by the diagonal Lines into 100 equal Parts, the Number of Links in a Chain; and, consequently, any Number of Chains of Links may be set off by this Scale. A little Consideration of the Figure will sufficiently explain it's Nature, and render it's Use very easy and expeditious. If one of the large Divisions are reckoned 10 Chains, then every one of the smaller Divisions will be 100 Links, and consequently you can only measure within 10 Links of the Truth, every smaller Division, which signifies 100 Links, being subdivided by the diagonal Lines into 10 Parts only. But the Practitioner should always remember to make Use of as large a Scale as possible, especially if he would have his Work exact, and always to reckon one of the large Divisions one Chain only, as the Dimensions of any Field or Parcel of Land may then be plotted with the greatest Accuracy.

To measure a Close or Field by the Chain, plot it on Paper, and find it's Content.

[See Fig. 2.]

Let ABCDE represent the Close or Field to be measured and plotted by the Chain only. In order to do this I begin at the Corner A, and measuring in a straight Line to the Corner D, which I find 30 Chains, 88 Links, and note it down in my Paper. Then I measure along the Side of the Hedge from D to E and find it 10 Chains 70 Links, which I also note down. From thence I measure along the Side of the Fence from E to A, and having found it 30 Chains 30 Links, I note it down; and proceed in my measuring from A to B, which I find 20 Chains 58 Links. From the Corner B I measure to the Corner D, and find it 30 Chains 55 Links. From D I measure to the Corner C, and find it 10 Chains 48 Links: And from C to B 20 Chains 39 Links. Then I have taken all the requisite Dimensions. The next Operation is

To Plot the above Field on Paper

In order to [do] this I draw a Line from A, representing my first Station, of a sufficient Length, and take from my diagonal Scale 30 Chains 88 Links, and placing one Foot of the Compasses in the Point A, set off the Distance to D, which will represent the Corner of the Field I measured to from A. Then I take from my Scale 10 Chains 70 Links, and setting one Foot of the Compasses in D, describe the small Arch *ef*. I also take from the same scale 30 Chains 30 Links, and placing the Point of the Compasses in A, describe with the other the small Arch *gh*, cutting the former in E; and draw the Lines ED and EA. Then I take from Scale 20 Chains 58 Links, and setting one Foot of the Compasses in A, and with the other describe the small Arch *ik*. I also take 30 Chains 55 Links from my Scale, and setting one Foot of the Compasses in D, with the other sweep the small Arch *lm*, cutting the former in B; and draw the Line AB, and the dotted Line BD. Lastly I take 20.39 from my Scale, and from B sweep the same Arch *ab;* and with 10.48 sweep, from D, the small Arch *cd*, cutting the former in C; and draw the Lines BC and DC. Thus is the Plot finished; and every Part of it may be measured by applying it to the same Scale. Nothing now remains but

To find the Content of the Field

The Field is divided by the dotted Lines AD and BD into three Triangles, ADE, ABD, and BCD, and consequently, the Contents of these three Triangles when added together will give the Content of the whole Field: But before these Contents can be found, the Lengths of the Perpendiculars EG, DF, and CH must be measured in the following Manner: Place one Foot of the Compasses in E, and extend the other until it will just touch the Line AD, but not cut it, and measure the Distance between the Points of the Compasses on the Scale, 10 Chains 45 Links. Do the same by the Perpendiculars DF and CH, and you will find the former 30.47 and the latter 10.9 [10.09?]. Having thus found the Lengths of the three Perpendiculars, the Areas of the three Triangles will be easily found by the Rule laid down for finding the Content of a Triangle, in the Article of Measuring Superficies.

For the Triangle ADE,

3088	Length of the Base
522	Half the Perpend.
6176	
6176	
15440	
1611936	

For the Triangle ABD

2058	Base
1523	Half Perpend.
6174	
4116	
10290	
2058	
3134334	

For the Triangle BCD

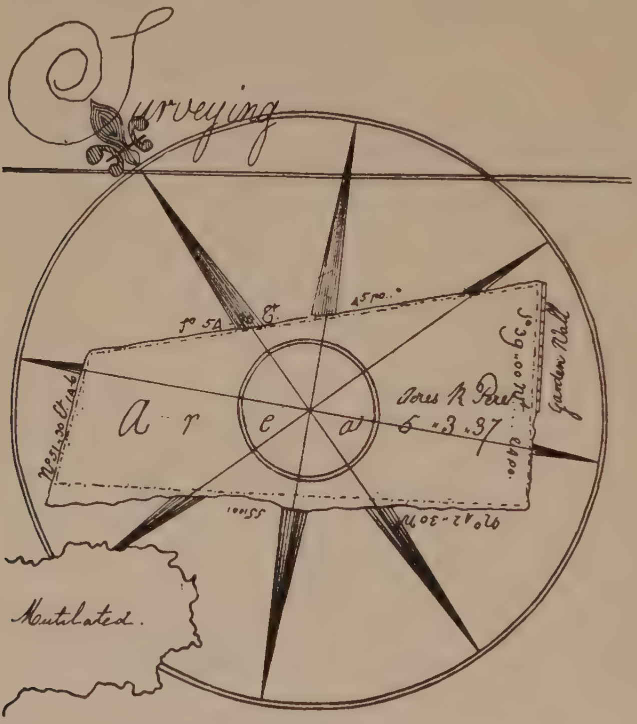
3055	Base
504	Half Perpend.
12220	
152750	
1539720	

	1611936	1st Triangle
	3134334	2d Triangle
	1539720	3d Triangle
Acres	62.85990	
	4	
Roods	3.43960	
	40	
Perches	13.38400	

Thus the Area of the Field is 62 Acres, 3 Roods, and 13 Perches.

Of course, this "course" in surveying was quite meager. Mr. Williams, pleased at the young fellow's desire to learn, helped him out by explaining the use of the surveyor's compass (the transit instrument was a later invention), and encouraged his practicing the art until he was quite proficient.

Young George definitely decided he would like to be a surveyor, and in order to fit himself more thoroughly for his profession he used to run practice surveys in the neighborhood, thus making sure of digesting the teachings of the "Young Man's Companion" and of Mr. Williams. One of his practice surveys is that of Lawrence Washington's turnip field (Fig. 3). A sample set of field notes is the following:



A Plan of Major Law: Washingtons Turnip Field as
Survey'd by me
This 27 Day of February 1747/8 GW

FIG. 3

> August 18th 1747 Then survey'd the following Piece of Land at one Station in the School House old field bounded as p^r field Book. Viz^t Beginning near a Persimon within y^e field Extending thence to a Fence Stake S 15–00 E 165°,, 00′–28 Pole thence S 19–00 W 199°–00′–27.5 Pole thence S 47 W 227°–00′ 18.9 thence S 76–00 W 256°–00′–21.4 thence N 42 W 318°–00′–46.3 thence N 29–00 E 29°–00′–34 Pole.

But let us not laugh at this casual preparation for an engineering career. Organized engineering curricula are of comparatively recent origin.

Of his notes kept at this period one of the most interesting is one copied from those of a survey by James Genn. The notes are as follows, the plat being Fig. 4:

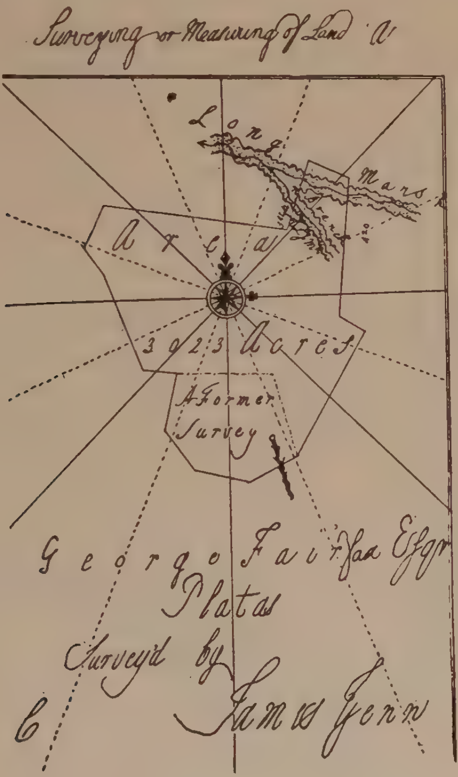


Fig. 4. — A Study illustrating "The Mannor how to Draw up . . .", etc.

The Mannor how to Draw up a Return when Survey'd for His Lordship or any of y^{e} Family.

March y^{e} 15th 1747–8

Then Survey'd for George Fairfax Esqr. Three Thousand & twenty Three Acres of Land lying in Frederick County on Long Marsh Joyning Thomas Johnstones Land and bounded as follows

Beginning at (A) Three Hickorys Corner Trees to Thomas Johnstones Land & Extending thence along his S 13 W^{t} One hundred Seventy two Poles to (B) a Locust

Johnstones Corner thence along another of his Lines S 34 E^t 150 po. to (C) a White Oak another of his Corners thence S^o 75 E^t 186 po & to (D) a large Hickory thence N^o 58 E^t 160 po xing [crossing] a Spring Run to (E) three Red Oak Fx on a Ridge thence N^o 30 E^t 436 po to a Hickory an Red Oak Fx at (F) thence N^o 60° W^t 90 po to (G) a Large White Oak Fx thence N^o 7 E^t 420 po xing Long Marsh to (H) two Red Oaks and a W: O: Fx in a Bottom in y^e afores^d Thomas Johnstones line finally along his line S^o 80 E^t one Hundred fourteen Poles to y^e Beginning Containing Three Thousand & twenty three Acres.

p^r JAMES GENN HENRY ASHBY RICHARD TAYLOR	*Chain Men*
ROBERT ASHBY	*Marker*
WM. LINDSEY	*Pilot*

N. B. The Distances in y^e above Writing ought to be Written in Letters not in figures only I have done it now for Brevity sake.

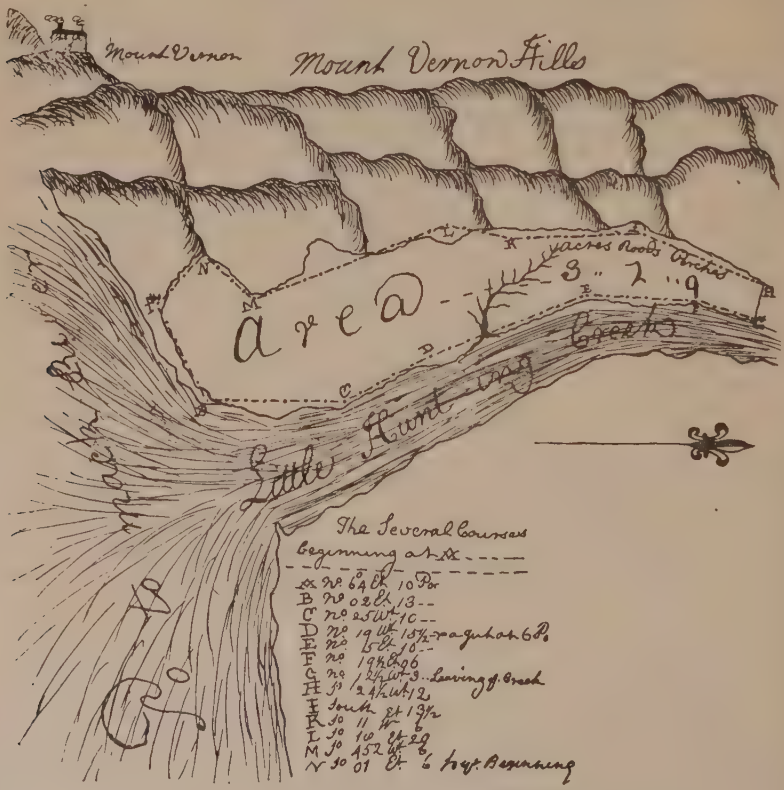


FIG. 5. — MOUNT VERNON HILLS, 1747
(Traced from original)

Other early surveys are illustrated by Figs. 5 and 6, showing the country about Mount Vernon house and Hell Hole, respectively.

At an early age he thus learned to be methodical. All his affairs were attended to systematically, and full records were kept.

According to Sparks, Washington not only was able to use logarithms in making his calculations, but apparently got up a system of statistical mathematics for himself. On every occasion he reduced information to graphs and tables for the better digestion of the facts.

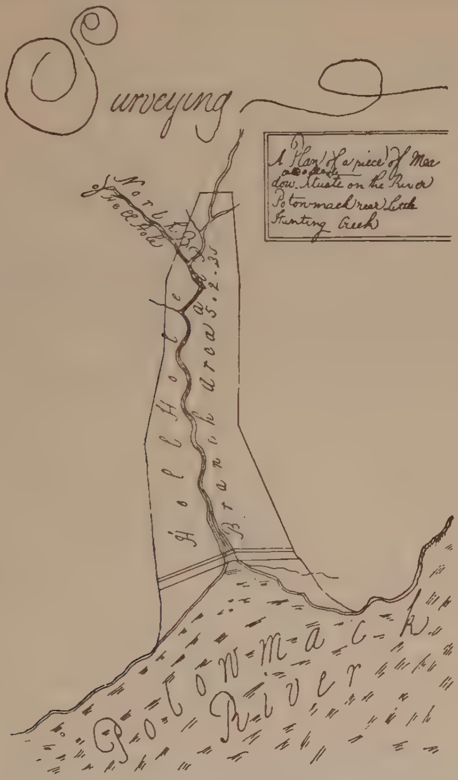

Surveying
A Plan of a piece of Meadow Situate on the River Potowmack near Little Hunting Creek
North Branch of Hell Hole
Hell Hole
Branch
5.2.30
Potowmack River

Fig. 6. — Survey of Land known as Hell Hole

> The constructing of tables, diagrams, and other figures . . . was an exercise in which he seems at all times to have taken much delight. . . .
>
> While at the head of the army this habit was of especial service to him. The names and the rank of the officers, the returns of the adjutants, commissaries, and quartermasters were compressed by him into systematic tables, so contrived as to fix

strongly in his mind the most essential parts, without being encumbered with details. When the army was to . . . perform any movement . . . a scheme was first delineated; and at the beginning of an active campaign . . . the line of battle was projected and sketched on paper, each officer being assigned to his post, with the names of the regiments and strength of the forces he was to command. [An example of this is Fig 7.]

During the presidency it was likewise his custom to subject the treasury reports and accompanying documents to the process of tabular condensation . . . it enabled

FAC SIMILE.—Copied from a Manuscript in the handwriting of Washington.

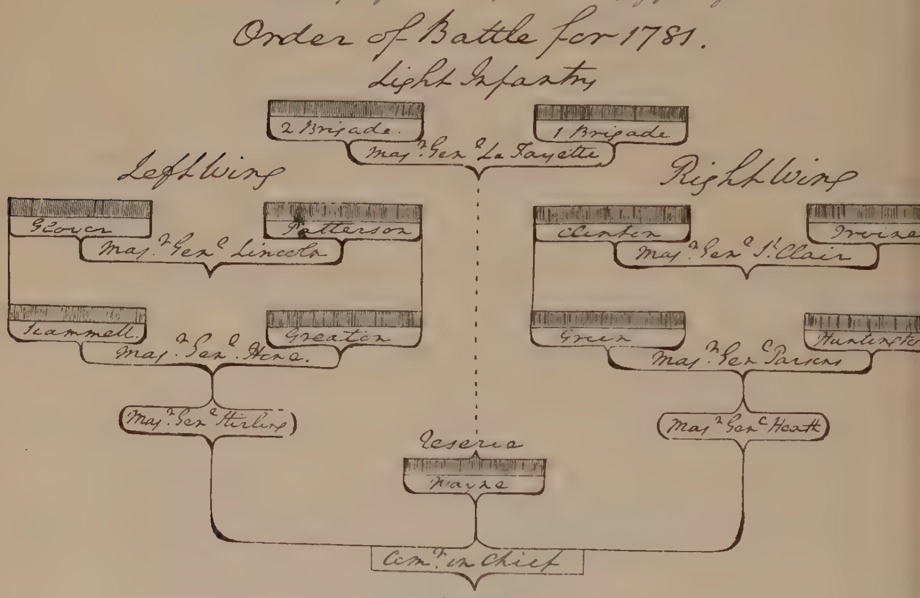


Fig. 7

him to grasp and retain in their order a series of isolated facts, and the results of a complicated mass of figures, which could never have been mastered so effectually by any other mode of approaching them. Such were some of the benefits of those parts of his education, to which he was led by the natural bent of his mind.*

But the future President was not a "grind" during his boyhood. His leisure moments he filled with manly sports. There was not a better or a more daring horseman than this tall, husky boy of fifteen who was well to the fore in every fox hunt. He could wrestle with the best of his companions, and as a drillmaster in the mimic warfare which the boys of that day effected he was an acknowledged expert. Withal,

---

* Jared Sparks, Life of Washington, 1837, pp. 8, 9, 10.

George had a reputation for probity which caused all disputes to be left to his arbitration, and no objection was ever made against his decisions.

He had now become almost sixteen years of age. His boyhood was over. Now he was to take his place among men.

He had taken full advantage of his education and had become a competent surveyor as far as theory was concerned. All he needed was practice, and that was soon forthcoming.

III

Lord Fairfax, a neighbor to the Washingtons, was an elderly and affluent bachelor, who, having visited Virginia, forsook his native England and came to live in the New World. He was an enthusiastic huntsman, as was young Washington, and thus they were brought constantly together.

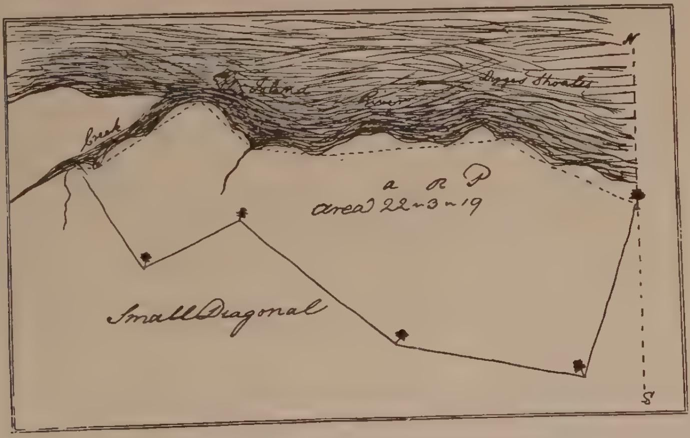


Fig. 8. — Mount Vernon River Front at Mouth of Hunting Creek

Lord Fairfax owned a huge grant of land on the other side of the Allegheny Mountains. This had never yet been surveyed, nor, indeed, been looked after in any way at all. His Lordship decided to survey the land, divide it into lots, and discourage the squatters who were making free there. To George Washington he offered the job of surveyor. Needless to say, the offer was quickly accepted. Preparations were speedily completed, and the party, consisting of George Washington, George Fairfax, a nephew of Lord Fairfax, and some assistants, started out. At Mr. Neville's, in Prince William County, Mr. James Genn, a licensed surveyor, joined them.

It was while on this trip that young Washington first began keeping his diaries, which are now of great historical value. We have room for only a few selections.

> Fryday, March 11th 1747–8. Began my Journey in Company with George Fairfax, Esqr.; we travell'd this day 40 miles to Mr George Neavels in Prince William County.

The double dating of the year was due to the following reason: January 1 was accepted as the beginning of the historical year, while March 25 was held by some to be the beginning of the civil or legal year. Double dating was used between January 1 and March 25 of the year, the single date being used the rest of the year. When the Gregorian (new style) calendar was adopted by Britain in 1752 this double dating stopped. The year of this Journal is 1748.

> Saturday March 12th this morning Mr James Genn ye surveyor came to us, we travell'd over ye Blue Ridge to Capt Ashbys on Shannondoah River, Nothing remarkable happened.
>
> Monday 14th We sent our Baggage to Capt Hites (near Frederick Town) went ourselves down ye River about 16 Miles to Capt Isaac Penningtons (the Land exceeding Rich & Fertile and all ye way produces abundance of Grain Hemp Tobacco &ca) in order to lay of some Lands on Cates Marsh & Long Marsh.

Work was started promptly the same day, as is testified by the following field notes:

> March y. 15th 1747–8. Survey'd for George Fairfax Esqr. a Tract of Land lying on Cates Marsh and Long Marsh beginning on three Red Oaks Fx on a ridge the No Side a Spring Branch being corner to ye 623 Acre Tract & Extending thence No 30° Et 436 poles to a Large Hickory and Red Oak Fx near John Cozines House thence No 60° Wt 90 poles to a Large White Oak Fx thence No 7° Et 365 poles to Long Marsh 420 poles to 2 Red Oaks and W: Oak in a Poyson'd field by a Road thence No 65° Wt 134 poles to a W: Oak by ye sd Marsh thence crossing ye Marsh So 20° Wt 126 poles to another Branch: of Long Marsh 218 po: to a Red Oak Fx thence No 80° Wt 558 po: to a Large Red Oak & White Oak Fx in a Valley thence So 25° Wt 144 poles to a Black Walnut in a Poyson'd Field by a Lime Stone Rock thence So 33½° Et 96 to a White Oak thence So 80° Et 316 po. to three Red Oaks in a Bottom in Wm Johnstones line thence with Johnstones So 80° Et 30 po to a Double Hickory Collo Blackburns corner 114 po to 3 Hickorys Johnstones corner & corner to ye aforesaid 623 Acre Tract thence along ye lines thereof East 280 poles to 3 Red Oaks finally along another of the lines thereof So 15° Et 262 po to ye beginning
>
> HENRY ASHBY } *Chain Men*
> RICHARD TAYLOR }
> ROBERT ASHBY *Marker*
> WM LINDSEY *Pilot*

The "marker" was probably rodman; the "pilot," instrumentman.

The following notes describe a rectangular lot. Apparently George Washington did not have any difficulties about his closures. Note that the pilot's name is not mentioned. George himself was probably instrumentman.

> March 29th 1748. Surveyed for Mr. James Rutlidge ye following a piece of Land Beginning at 3 W. O. in ye Mannor Line by a Path leading to y. Clay Lick & Extending thence N° 44° Wt 164 po. to a White Oak by a Drain at ye foot of a Mountain thence N° 46 Et 487 po. to 2 White Oaks near a Branch call'd Clay Lick Run thence S° 44° Et 164 po. to 2 W. O: & a Hickory in ye Mannor Line Finally along ye Mannor Line Reversed S° 46° Wt 487 po to y. Beginning.
>
> HENRY ASHBY } *Chain Men*
> RICHARD TAYLOR }
> WM DUNCAN *Marker*

Washington acquitted himself creditably on the expedition and returned home on Wednesday, April 13, 1748. From the general language of the Journal kept on the expedition, it is clear that he was the Chief of Party — quite a responsibility for a lad of sixteen. It must be remembered that he not only had to survey the tracts, but *find them also*, the general location having been given, but in all probability without a map to guide him.

Having acquitted himself as a man, the young surveyor naturally looked about for permanent employment in his beloved profession. Through the efforts of Lord Fairfax the young man was appointed county surveyor. Being thus licensed, his surveys became clothed with the authority of court records, and — a less desirable state of affairs — he had to pay over part of his fees to William and Mary College, the licensing authority.

For three years in all he practiced his profession. A letter, written by him during this period, describes to some extent his life at the time. The spelling and punctuation are as corrected by Professor Sparks.

> DEAR RICHARD: — The receipt of your kind favor of the 2d instant afforded me unspeakable pleasure; as it convinces me that I am still in the memory of so worthy a friend, — a friendship I shall ever be proud of increasing. Yours gave me the more pleasure, as I received it among barbarians and an uncouth set of people. Since you received my letter of October last, I have not slept above three or four nights in a bed, but, after walking a good deal all day, I have lain down before the fire upon a little hay, straw, fodder, or a bearskin, whichever was to be had, with man, wife, and children, like dogs and cats; and happy is he, who gets the berth nearest the fire. Nothing would make it pass off tolerably but a good reward. A doubloon [about $7]

is my constant gain every day, that the weather will permit of my going out, and sometimes six pistoles [three doubloons]. The coldness of the weather will not allow of my making a long stay, as the lodging is rather too cold for the time of the year. I have never had my clothes off, but have lain and slept in them, except the few nights I have been in Frederictown.

His notes were neatly kept as usual. The following examples will no doubt be of interest. The first example is a survey of Mr. Francis Jett's land. (See Fig. 9.) Note how he measured his line across the stream.

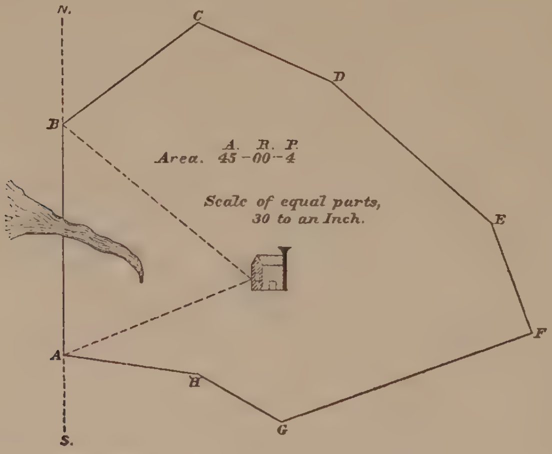


FIG. 9. — FRANCIS JETT'S LAND

Then Survey'd for M^r Francis Jett the following Tract of‸Land Bounded as p^r Field Book.

[Station]	[Course]	[Poles]
A	N.	56.15
B	N 51–00 E	39.19
C	S 65–00 E	34.14
D	S 49–00 E	50.15
E	S 20–00 E	29.00
F	S 70–00 W	62.13
G	N 58–30 W	20.24
H	S 83–30 W	30.00

Remarks y^e distance from A to B being Inaccessable I took an angle within y^e field from A to a house bearing N 73°–00 E 46 Pole thence to B bearing N 48–00 W.

Fig. 10 illustrates another survey.

Survey'd for Mrs Elizabeth Washington ye Following Tract of Land whose thirds is required to be laid of 20 Pole from H towards K & the Division line to run towards BC.

A	S 54,, 00 E	67,, 00
B	N 45,, 00 W	36,, 00
C	N 76,, 00 W	45,, —
D	N 31,, 00 E	60,, —
E	N 56,, 00 E	35,, —
F	N 21, 00 E	30,, 24
G	S 51,, 00 E	40,, 20
H	S 34,, 00 E	41,, 60
I	S 04,, 00 W	34,, 20

	Acres	Roods	Perch
Area	52,,	1,,	39,,

Scale 50 Parts to an Inch

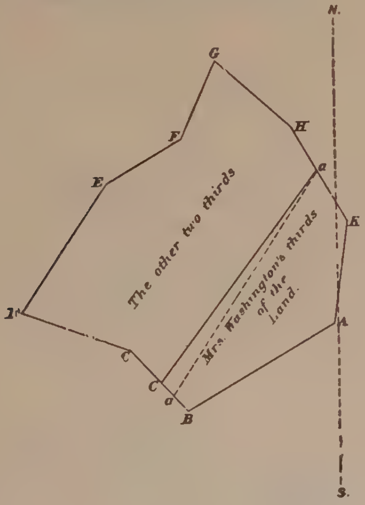


FIG. 10.—ELIZABETH WASHINGTON'S LAND

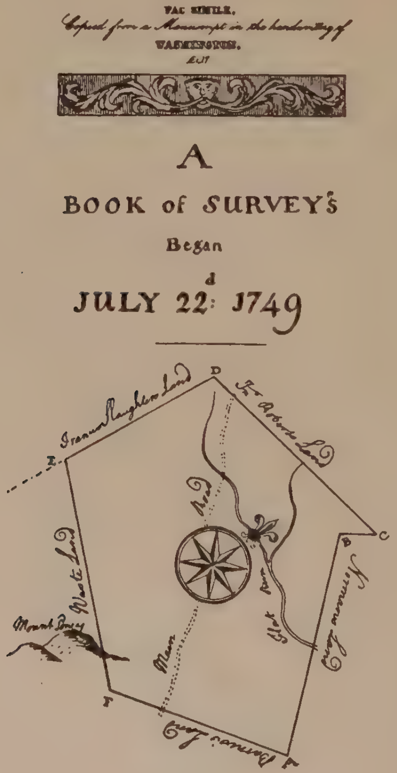
Fig. 11 is the plat of a lot, and is also used as the title-page for a field book.

Survey'd for Richard Barnes Gentn of Richmond County a certain Tract of Waste and ungranted Land Situate Lying and being in the county of Culpeper and Bounded as followeth Beginning at three white Oaks in Normans Line and Corner Trees to (Aaron Pinson's now) Mr Barnes's Land & Extending thence N° 42° 30′ Wt Ninety five Poles to a Branch of Flat Run Two hundd and Eighteen Poles to a Large White Oak Corner to Norman thence along another of his Lines N° 39° Et Thirty four Poles to three white Oaks & a Hickory Cor: to the said Norman and John Roberts thence along Robert's Line S° 78° Wt One hundd and Eighty three Poles to the Road that

Leads over Norman's Foard Two hund^{d} and Sixteen Poles to two white Oaks in a Glade Cor^{r} to the said Roberts and M^{r} Francis Slaughter thence with the said Slaughters Line S^{o} 5° W^{t} One hund^{d} and Sixty four Poles to three white Oaks in the said Slaughter line thence leaving his Line S^{o} 66° E^{t} Two hund^{d} and thirty Six Poles to three white Oaks amongst a Parcel of Rock Stones Barnes's Corner thence with his Line N° 53° E^{t} One hund^{d} and Eighty Six Poles to the Beginning Containing Four Hundred Acres this Twenty Second Day of July 1749.

WASHINGTON SCC

JOHN LONEM } *Cha Men*
EDWARD CARDER }
EDWARD HOGAN *Marker*



FAC SIMILE.
Copied from a Manuscript in the handwriting of
WASHINGTON.

A

BOOK of SURVEYS

Began

JULY 22^{d}: 1749

FIG. 11. — SURVEY FOR RICHARD BARNES, GENT.

"Washington SCC" is supposed to mean "Washington, Surveyor Culpeper County."

Fig. 12 represents two lots of a subdivision on the "Cacapehon" or Lost River.* They belong to Francis and William McBride. A similar lot belonging to a Robert Denton adjoins it.

George Washington did quite a bit of surveying in that region. He was, in fact, a very popular surveyor, his popularity being due to his exactitude. Later surveys — and even recent ones — could not find any errors in his courses and measurements.

This is all the more remarkable when we remember the numerous sources of error possible with a chain, and that a great deal of surveying in Washington's time was done by means of the chain alone, the angles being laid out by latitude and departure measurements in the field, with the values found in tables of natural functions of angles. If we recollect rightly, "Breed and Hosmer" does not include this method as standard.

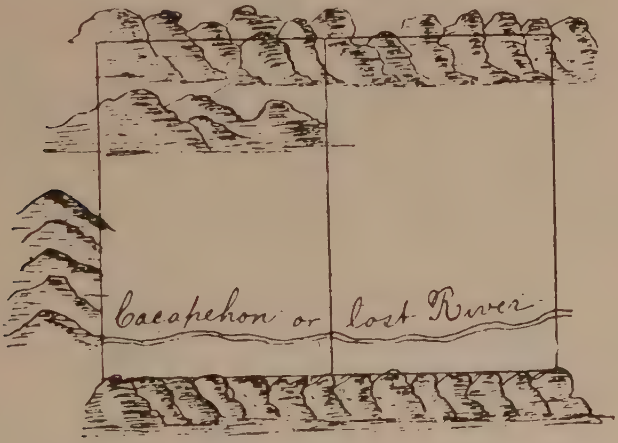


FIG. 12.—THE LANDS OF FRANCIS AND WILLIAM McBRIDE, LOST RIVER

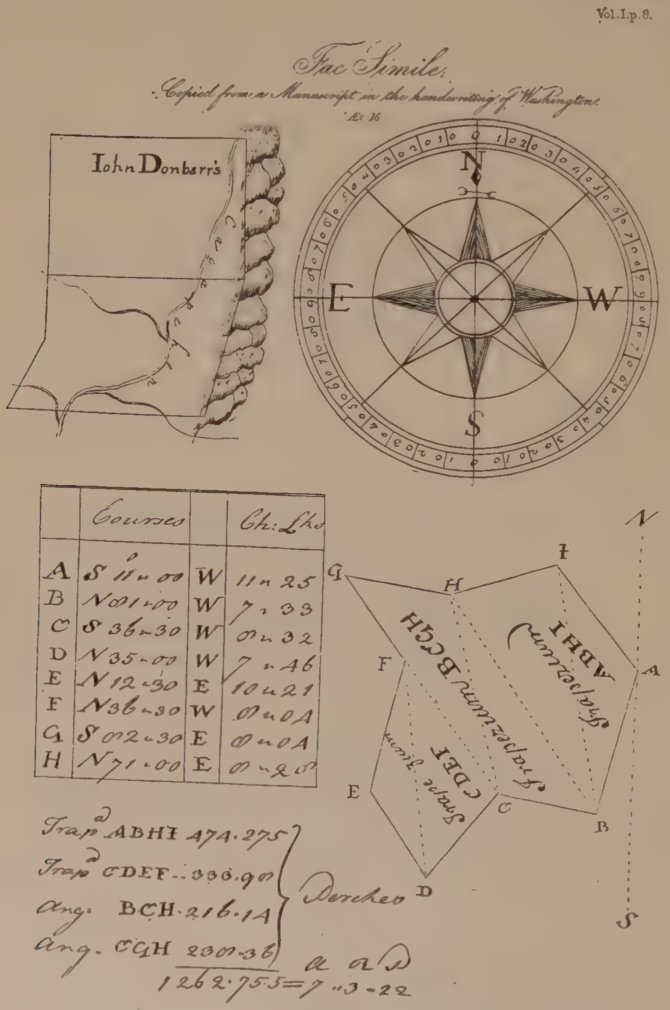
But this phase of his career was soon to close. His elder brother Lawrence became ill of pulmonary tuberculosis and went to Barbados to cure himself. George went with him. The tropical air was of no aid to the sufferer, however. Lawrence Washington died. George came back to live at Mount Vernon, the property having become his.

He soon left home to fight in the French and Indian War, having been appointed a major in the provincial forces. He came back, covered with glory and the foremost soldier in the colonies.

---

* So called because for three miles it is subterranean.

At Mount Vernon he stayed from the close of the French and Indian War to the outbreak of the Revolution. During that time he married, became a vestryman, a Burgess, and quite a power in the community. Of his services in the Revolution we need not speak here.



Vol.I.p.8.

Fac Simile.

Copied from a Manuscript in the handwriting of Washington.

Æt 16

	Courses		Ch: Lks
A	S 11..00	W	11..25
B	N 01..00	W	7..33
C	S 36..30	W	00..32
D	N 35..00	W	7..46
E	N 12..30	E	10..21
F	N 36..30	W	00..04
G	S 02..30	E	00..04
H	N 71..00	E	00..25

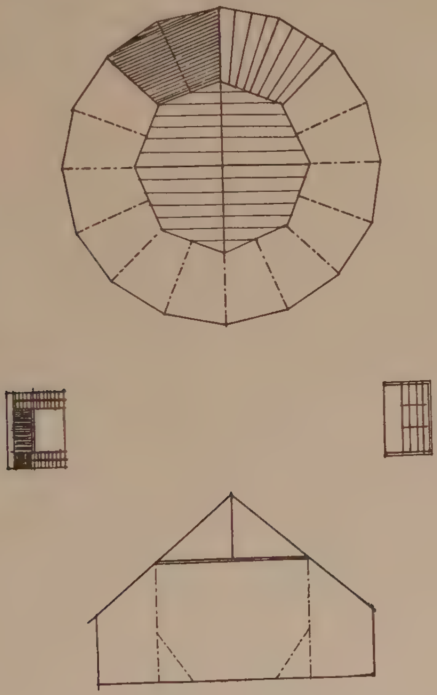
Trap^d ABHI 474.275
Trap^d CDEF..336.90
Ang: BCH.216.14
Ang. CGH 230.36
} Perches

1262.755 = 7..3..22
a r p

FIG. 13

IV

We will now pay some attention to our first President as an agriculturist. In these days, when there are enough varieties of engineers to make Vitruvius turn over in his grave, it is rather difficult to forbear enrolling our illustrious subject in the ranks of agricultural engineers.



WASHINGTON'S 16-SIDED BARN
(FROM HIS PLAN)

FIG. 14

He designed all his farm buildings, experimented with crops, and ran an experiment station of his own, the results of which he put to good use in running his estate. Of his plans for agricultural buildings, Fig. 14 shows part of his plan for a sixteen-sided barn, built in 1793. He calculated that 140,000 brick would be required for it. These were made on the estate. The threshing-floor was 30 feet square with 1½-inch spaces left between the boards so that the grain when trodden out by horses or beaten out with flails would fall through to the floor below, leaving the straw above.

He constantly endeavored to rouse his neighbors from their shiftlessness, but to no purpose. They persisted in their unscientific farming and envied his profits. Lack of space does not permit examples of his minute planning for rotation of crops.

Not only was he the country's foremost agriculturist, but he devised and used much labor-saving machinery. The following extracts from a letter to Theodoric Bland describe and explain the use of a "drill plough" which he devised.

MOUNT VERNON, 28 December 1786.

DEAR SIR: — I am now about to fulfill my promise with respect to the drill plough and timothy seed. . . .

To give you a just idea of the use and management of it, I must observe that the barrel at present has only one set of holes, and those adapted for the planting of Indian corn, only eight inches apart in the row; but by corking these, the same barrel may receive others of a size fitted for any other grain. To make the holes, observe this rule; begin small and increase the size, till they admit the number of grains, or thereabouts, you would choose to deposit in a place. They should be burnt, and done by a guage, that all may be of a size, and made widest on the outside to prevent the seeds choking them. You may, in a degree, emit more or less through the same holes, by increasing or lessening the quantity of seed in the barrel. The less there is the faster it issues. The compressure is increased by the quantity, and the discharge is retarded thereby. The use of the band is to prevent the seeds issuing out of more holes than one at a time. It may be slackened or braced according to the influence the atmosphere has on the leather. The tighter it is, provided the wheel revolves easily, the better. By decreasing or multiplying the holes in the barrel, you may plant at any distance you please. The circumference of the wheels being six feet, or seventy-two inches, divide the latter by the number of inches you intend your plants shall be asunder, and it gives the number of holes required in the barrel.

By the sparse situation of the teeth in the harrow, it is designed that the ground may be raked without the harrow being clogged, if the ground should be cloddy or grassy. The string, when this happens to be the case, will raise and clear it with great ease, and is of service in turning at the ends of rows; at which time the wheels, by means of the handles, are raised off the ground, as well as the harrow, to prevent the waste of seed. A small bag, containing about a peck of the seed you are sowing, is hung to the nails on the right handle, with a small tin cup the barrel is replenished with convenience, whenever it is necessary, without loss of time, or waiting to come up with the seed-bag at the end of the row. I had almost forgot to tell you that, if the hole in the leather band, through which the seed is to pass, when it comes in contact with the hole in the barrel, should incline to gape, or the lips of it turn out, so as to admit the seed between the band and the barrel, it must be remedied by riveting a piece of sheet tin, copper, or brass, the width of the band, and about four inches long, with a hole through it, the size of the one in the leather. I found this effectual. I am, dear Sir, &c.

He must have sent a sketch with the letter. The spelling and punctuation are as corrected by Professor Sparks.

Washington kept a diary, from which are taken the following extracts:

> January 1st 1760 — Visited my plantations, and received an instance of Mr. F.'s great love of money, in disappointing me of some pork because the price had risen to twenty-two shillings and sixpence after he had engaged to let me have it at twenty. Found Mrs. Washington upon my arrival broke out with the measles.
>
> 8th Directed an indictment to be formed by Mr. Johnston against J. B. for a fraud in some iron he sold me.

Evidently Colonel Washington believed in living up to specifications.

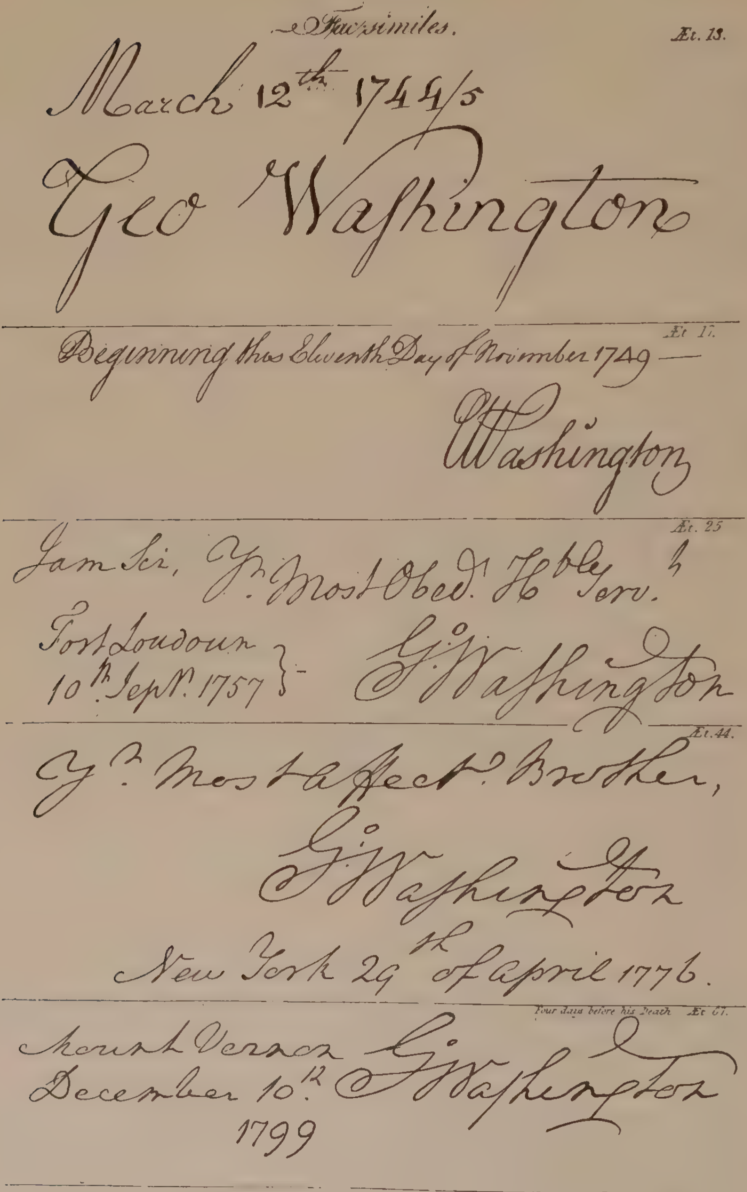
> February 10th Ordered all the men from the different quarters to assemble at Williamson's quarter in the morning to move Petit's house.
>
> March 6th Fitted a two-eyed plough, instead of a duck-bill plough, and with much difficulty made my chariot wheel-horses plough.
>
> 7th — Put the pole-end horses into the plough in the morning and put in the postillion and hind horse in the afternoon, but the ground being well swarded over, and very heavy ploughing, I repented putting them in at all, for fear it should give them a habit of stopping in the chariot.
>
> 14th — Mr. Carlyle and his wife still remained here. We talked a good deal of a scheme of setting an iron-works on Colonel Fairfax's land on Shenandoah.
>
> 17th — Went to my mill and took a view of the ruins, which the fresh had caused; determined, however, to repair it with all expedition, and accordingly set my carpenters to making wheel and hand barrows.
>
> 19th — Peter (my smith) and I, after several efforts to make a plough after a new model, partly of my own contriving, were fain to give it over, at least for the present.
>
> 26th — Spent the greatest part of the day in making a new plough of my own invention.

When he had no machinery, he just went ahead and made it himself.

V

As a land developer he was way ahead of his time. He knew that the young, lusty Nation must grow. In order to grow, it must have more land. He therefore lent all possible aid to settlers in the West. He bought up a lot of land in the Ohio country, which he tried to rent out to cultivators. A great deal of the land he received for services in the French and Indian War; some he bought; some he staked out from unappropriated lands offered by Virginia.

He organized or took part in several companies whose aims were to develop waste land, such as the Great Dismal Swamp Company, the Mississippi Company and others.



Facsimiles.

Æt. 13.

March 12th 1744/5

Geo Washington

Æt. 17.

Beginning the Eleventh Day of November 1749 —

Washington

Æt. 25

I am Sir, Yr. Most Obedt. Hble Servt.

Fort Loudoun
10th Septr. 1757 } G:o Washington

Æt. 44.

Yr. Most affect. Brother,

G:o Washington

New York 29th of April 1776.

Four days before his Death Æt 67.

Mount Vernon
December 10th
1799
G:o Washington

Fig. 15

VI

Another great interest of his was in opening the navigable streams, so that the western part of the country might be connected by a network of canals with the eastern part. He held that when communications are easy the country can grow and be united.

In a letter to Richard Henry Lee, President of Congress, he urged that the western waters be explored, their navigable capabilities ascertained, and a complete map be made of the country; that in all grants for land by the United States there should be a reserve made for special sale of all mines, mineral and salt springs, and that a medium price should be adopted for the western lands, sufficient to prevent monopoly, but not to discourage useful settlers.

It is surprising how modern he was in all his views. The program mapped out to Mr. Lee is in many ways paralleled by recommendations made in recent directors' reports of the various government bureaus in charge of these matters. So far, of course, no systematic schemes have been followed. The country, for example, is not even now completely mapped in accordance with United States Geological Survey Standards. Neither has the Coast and Geodetic Survey been able to set itself a program that would be supported by Congress financially.

That Washington had good judgment on the use of various building materials, with which he was experimenting constantly, may be gathered from the following extract from a letter to Count de Moustier, under date of December 15, 1788:

> I have formerly been somewhat curious in making experiments relative to cements; particularly that which derives its name from Loriot, but have never been able to succeed to my wishes. I was delighted with the idea that the cement used by the ancients had in all probability been rediscovered. Some time in the late war I employed three or four of the principal French engineers in our army to make some mortar into a consolidated mass [concrete?], according to the printed directions for making Loriot's cement, with a copy of which they were furnished. But the result, after many trials, was infinitely distant from what we have been led to expect. As the process was strictly in conformity to the prescribed rules, I know not to what cause the failure of success should be attributed.

That he knew what good bricks are may be seen from the following instructions to his brickmakers, making bricks for a barn:

> . . . Gunner and Davis must repair to Dogue Run and make bricks there, at the place and in the manner which have been directed, that I may have no salmon bricks in that building.

Several books have been written concerning his supervision of the planning of Washington City by Major l'Enfant, so that no mention need be made here.

During the canalization of the Potomac River, one of the engineers proposed a means of doing away with the locks at the rapids. President Washington's opinion, expressed in a letter to Tobias Lear (December 21, 1794), is most interesting:

> The plan of Mr. Clairborne's engineer, as far as I understand it, is to avoid locks altogether. The vessels are received into a basket, or cradle, and let down by means of a lever and pulleys, and raised again by weight at the hinder extremity of the lever, which works on an axis at the top of a substantial post fixed about the center of the lever. On this principle, but differently constructed, Mr. Greenleaf a few months ago showed me a model of the efficacy of which he seemed to entertain the most exalted opinion. My doubts of the utility of both arise first, from the insufficiency of any machinery of this sort to bear the weight of the cradle when charged with water and a loaded boat therein, and its aptness to get out of order by means thereof; secondly, I do not find that they are in general use; and thirdly, because if I recollect rightly, Mr. Weston has told me, but of this I am not certain, that no method of raising and lowering boats has been found equal to that of locks. Still, as I observed in my last, I should be for hearing the opinions and explanations of any and every scientific and practical character that could be easily got at on this subject, and therefore would hear Clairborne's engineer, as well as Mr. Weston. . . .

He gave great encouragement to James Rumsey, who was working on the invention of a steamboat. Rumsey, however, died in London before he could perfect it.

In 1780 the American Philosophical Society elected him to membership. The following letter to President Reed was written in reply to the announcement of his election:

> MORRISTOWN, 15 February, 1780
>
> SIR: — I am much indebted to your Excellency for announcing my election as a member of the Philosophical Society. I feel myself particularly honored by this relation to a society, whose successful efforts for promoting useful knowledge have already justly acquired for them the highest reputation in the literary world. I entreat you to present my warmest acknowledgments and to assure them that I shall with zeal embrace every opportunity of seconding their laudable views, and manifesting the exalted sense I have of the institution. The arts and sciences essential to the prosperity of the State, and to the ornament and happiness of human life, have a primary claim to the encouragement of every lover of his country and of mankind. With the greatest respect and esteem, I am, Sir, &c.

VII

Such are the high lights of the unemphasized parts of George Washington's career. Full justice has not been done, owing to lack of space. It is hoped that enough has been said to make us all proud of George Washington, not only for what the world knows him as, — a soldier, statesman and patriot, — but also as a high type of engineer.

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Note. — Grateful acknowledgment is due to the following sources for the items enumerated:

1. Journal of My Journey Over the Mountains, J. M. Toner, Editor, Albany, 1892, for illustrations and for extracts from the diary.
2. Writings of Washington, Edited by Jared Sparks, Boston, 1837, for illustrations and for certain extracts as noted.
3. The Young Man's Companion, by W. Mather, London, 1750 (24th edition), for the section on Surveying, and for Figs. 1 and 2.
4. George Washington, Farmer, by P. L. Haworth, Indianapolis, 1915, for illustration of the barn.
5. George Washington, by Rupert Hughes, New York, 1926, for general information.

For the same reason, acknowledgments are due to —

6. George Washington, by Henry Cabot Lodge, Boston, 1889.
7. General Washington, by General Bradley T. Johnson, New York, 1898.
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STRUCTURAL DESIGN OF THE EAST BOSTON VEHICULAR TUNNEL

By Benjamin A. Loveland *

(Presented at a joint meeting of the Designers Section and Highway Section of the Boston Society of Civil Engineers on May 13, 1931)

The proposal to build a thoroughfare from Boston to East Boston by means of a bridge or a tunnel has been studied for many years. In 1868 plans for a bridge were discussed, and a tunnel was recommended by General Foster Corps of Engineers, United States Army, as being preferable. Various studies and reports by different authorities and boards were made from time to time during the next fifty years; notably in 1911, a joint board, composed of the Boston Transit Commission and the Board of Railroad Commissioners, made a second report upon this subject. Its conclusions were that under conditions existing at that time, with large use of animal power, the construction of a teaming tunnel would be inadvisable, but that when mechanical power should be more generally substituted for animal power the question might properly be reconsidered.

In 1921 another joint board, this time comprising the Division of Waterways and Public Lands of the Department of Public Works and the Boston Transit Department, after a two-year study which included a traffic count at the ferries, recommended the construction of a twin-tube traffic tunnel, but it was plainly stated, as the opinion of the engineers, that a single tube would carry all the traffic in both directions for some years to come.

Other Vehicular Tunnels

In 1927 the Holland tunnel was opened and at once proved to be a marked success. In that same year the first steps were taken looking toward building the Detroit–Canada tunnel, and in the next year the George A. Posey tube at Oakland, California, was opened to traffic.

The Detroit and Oakland tunnels are single-tube subaqueous automobile tunnels of about the same length as will be built in Boston.

---

* Assistant Engineer, Boston Transit Department.

Legislature Authorizes Tunnel

In 1929 the Legislature passed the necessary legislation permitting the city of Boston, acting through its Transit Department, to build a traffic tunnel, limiting the cost to $16,000,000, of which it was expected that $6,000,000 would be expended on street widenings leading up to the tunnel, and that $10,000,000 would be the cost of the tunnel. As soon as the city accepted the legislative act, the Transit Department proceeded with all the preliminary work, such as surveys, borings, land taking, etc., and in January, 1931, the Department advertised for bids to build Section A of the tunnel. This section, about 4,850 feet long, includes the portion under the harbor and also much that is under the land on each side, leaving only short sections at each end of the tunnel to be built later.

Single-Tube Tunnel

The plans provide for a single-tube tunnel, with a two-lane roadway accommodating one line of traffic in each direction and leaving sufficient width to permit of passing in the case of a disabled car. The tunnel will start from a point near Cross Street, between Hanover and North streets in Boston, and end just beyond Meridian Street, between London and Havre streets, in East Boston.

The 1921 report states that these points are close to the centers of areas, in Boston and East Boston, where 50 per cent of the ferry traffic by actual ten-day count was found to originate and terminate.

The total length of the tunnel will be a little more than a mile. In horizontal alignment it will be straight, a feature which should tend to increase its capacity over that of the existing single-tube subaqueous tunnels in America, both of which are curved. The tunnel for the most part will not pass under heavy construction. It crosses the harbor where the channel is approaching its narrowest place, and also crosses nearly at right angles to the general trend of the channel. This, together with the fact that the ends of the tunnel are on low ground, makes the length over all close to the minimum. The selected location is expected to serve the needs of both local and through traffic. It will also be nearly the lowest in cost of any that could be chosen.

Depth of Tunnel

The position, vertically, of the under-water portion of the tunnel is independent of the location. There must be sufficient earth over it to hold the compressed air during construction and also to protect it after it is built. The necessity of such protection is illustrated by the fact that on July 1, 1926, the steamer "Washington Irving" sank over the Holland Tunnel, then approaching completion, so that she rested on the mud bottom over the north and south tunnels. Due to the fact that there was a considerable depth of material over the tunnels at the point where the ship sank, there was no effect on the tunnels discernible from the settling of the "Washington Irving" over them. The present channel is 35 feet deep at mean low water, and in future will probably be dredged at least 5 feet deeper; also, there should be an allowance of a foot or two for overdepth in dredging. The top of the tunnel at the pierhead lines was accordingly fixed at 50 feet below mean low water. The maximum grade in any of the American traffic tunnels is about 5 per cent. The grade on the Boston side will be 4.2 per cent; that on the East Boston side will be 3.4 per cent. The grade on the East Boston side was diminished slightly, permitting the tunnel to pass under Meridian Street. This arrangement will allow traffic bound for the Albany Railroad terminal, the airport, and the North Shore to proceed without interference with the street cars and other traffic on that street.

The part of the tunnel now under contract has a circular cross section because it is particularly well adapted to the various requirements of an automobile tunnel and can most conveniently be built by the shield method. The shield method was adopted because it appeared to be more feasible and also lower in cost than the trench method, the only other method which seemed practicable.

Then, again, it was extremely doubtful if the War Department would have permitted the use of the trench method with the consequent blocking of the main ship channel.

The use of shields is not new in Boston. The Boston Transit Commission, the predecessor of the present department, used roof shields on three occasions, — Tremont Street tunnel, East Boston tunnel and Beacon Hill tunnel. It used full circle shields and compressed air in the twin tube, Dorchester tunnel. The successful construction of the tunnel by the shield method is regarded as certain.

DIMENSIONS OF TUNNEL

The outside diameter of the cross section is 31 feet, 1 foot 6 inches more than that of the Holland tunnel, and 8 inches less than that of the Detroit–Canada tunnel. The arrangement of the cross section is about the same as in all three of the American subaqueous automobile tunnels. The roadway is 21 feet 6 inches wide, as compared with 20 feet in the

Holland tunnel, and 22 feet in the Detroit–Canada tunnel. There are ducts for fresh air and exhaust air, a sidewalk for patrol purposes, ducts for electric cables, a water pipe for fire fighting purposes, with hose and fire extinguishers in wall niches, and equipment for electric lighting.

VENTILATION OF TUNNEL

The ventilation of this tunnel will be done in the same general way that it is done in all the existing subaqueous traffic tunnels; that is, fans in ventilation buildings, one building on each side of the harbor, will force fresh air into the tunnel and exhaust fans will pull the foul air out. The fresh air will go into a duct under the roadway. Flues spaced about 15 feet apart on each side of the fresh air duct will admit the fresh air to the roadway. The air will pass vertically upward and be drawn through ports into an exhaust air duct above the roadway from which fans in the ventilating buildings will draw it out. The ventilating shafts which will form part of the foundations of the ventilation buildings are included in the contract for Section A. They are in reality huge reinforced concrete boxes, waterproofed, and when the ventilation buildings are built will contain the curved partitions which will lead the air from the tunnel to the fans in the building above. The large circular openings through which the shield will be driven will be temporarily closed by bulkheads. They were designed to withstand the active earth pressure with a 5-foot surcharge or the pressure of ground water assumed to exist up to a level equal to mean high water in the harbor, whichever pressure was the greater. The walls of the shafts were designed for the same horizontal pressures as the bulkheads.

SHIELD SHAFT

There is a third shaft in Section A which is known as the construction or shield shaft. This is located on the East Boston side, and has a circular bulkhead at one end and a rectangular one at the other, because at this point the section changes from circular to a box, or so-called subway section. The shield will be erected in this shaft, the bulkhead will be removed, and the shield will begin its travel to Boston.

The shield will be a very sturdy steel cylinder stiffened with horizontal and vertical braces. It will have a cast-steel cutting edge projecting forward to form a hood at the top. It will be moved forward about 30 inches at a time by 30 hydraulic jacks. The total force these jacks can exert is about 4,500 tons.

Character of Earth

The material in which the shield-driven portion of the tunnel will be built, according to the testimony of the borings, will be, in general, blue clay. That was the material encountered in building the old East Boston tunnel, which is not far from this one, and it is the material found in the completed excavation for the shield shaft of this tunnel. It is dense, compact, impervious to water, and appears stiff enough not to put excessive pressure against the sides of excavations made in it. This clay is a very favorable material through which to drive a shield, as it holds compressed air well, and a good breast in front of the shield can be maintained.

All the earth which the tunnel displaces must be excavated, passed through the shield, and taken through the tunnel to a shaft, where it will be raised to the surface and disposed of for filling in the East Boston Airport. The cost of excavation will be $20 per cubic yard. The estimated quantity is 154,000 cubic yards for Section A. The method the contractor will adopt for excavating will be interesting. The use of power in excavating shield-driven tunnels has not been highly developed. Most of the work has been done by hand. The shield is commonly used to trim the excavation and, to some extent, to break down the earth around the outside after the center portion has been removed. The pressure required for a shove can be diminished by insisting that the ground ahead of the shield be fully excavated.

In the Detroit–Canada tunnel, where the ground was a stiff gray clay, excavation was done with drag knives operated by small electric hoists on the platforms of the shield, the workmen dumping the clay into chutes which delivered it to belt conveyors discharging into mucking cars. The shield for this tunnel has a chute, and it may be that a similar method will be used here.

Primary Lining of Steel

The first, or primary, lining which will be erected in the tail of the shield will be of steel. This will be the second large shield-driven tunnel to use steel for the primary lining. The first was the Detroit–Canada tunnel, where it met all requirements. The usual material has been cast iron, although wood was used in the Dorchester tunnel; brick was used in the Tremont Street tunnel; and concrete in the old East Boston and Beacon Hill tunnels. Brick was used in the first Thames tunnel, where the shield, the invention of Brunel, was first employed.

Steel was selected here because it makes a lighter, much cheaper and more flexible lining than cast iron. A comparison between the cost of cast iron and steel as a lining material for this tunnel can be easily made. A cast-iron lining would weigh about three times as much as this steel one. It would cost about two-thirds as much per ton. The total cost would then be more than twice as much as the steel lining. The total weight of the steel lining is about 12,000 tons, and the contract price is $113 per ton. The lining is made in rings 30 inches wide and 8 inches deep, with bolted joints between rings. The width is 30 inches because that seems to be the length of shove which experience has shown to be best. Many of the tunnels built in the last thirty years have had 30-inch rings. Each ring is divided into eleven segments, and a key by eleven radial and equidistant joints, and a twelfth joint which is oblique and near a radial joint. Ten of the segments are alike and are interchangeable. They are called the A segments. The eleventh segment is odd and is called the B segment. Combined with the key, a combination is formed which is equal in length to an A segment. The necessity for a key segment, in which the length on the outside is less than that on the inside in order to complete the ring, is obvious, inasmuch as the ring is erected from the inside. The A segments weigh close to 1,200 pounds each. The weight of a complete ring is 6.5 tons. The erection of the lining will be done by an erector arm on the shield operating by power.

A percentage of the rings will be taper rings, that is, rings narrower by 2 inches at a point diametrically opposite the key. By means of the taper rings, the changes of grade in the tunnel can be accomplished and the lining can be made to follow the shield if it gets slightly off line and grade. The taper rings involve five more different segments. The total number of unlike segments used to build the shield-driven part of the tunnel will be eight. Each segment consists of a three-eighths inch thick skin plate, the stiffeners, the reinforcing angles, and the end plates. The skin plate is pressed into a channel shape with 8-inch flanges, and also curved to the required radius in a heavy press. The stiffeners, which, in this lining, are 45-pound tee rails, after being faced on the ends are welded to the back of the skin plate on the inside so that their ends abut against the outstanding legs of the skin plate. The reinforcing angles, after being curved, are welded to the outstanding legs of the skin plate. The ends of the segment are closed by one-half inch thick end plates welded on after the plate and angles have been faced. The 2-inch grout hole is made and plugged, and the seven-eighths inch holes for three-quarters inch connecting bolts are then punched, completing the segment. The accuracy of manufacture of the lining is expected to be high. The tolerances for the overall dimensions are one-thirty-second of an inch. Two rings of the Detroit–Canada tunnel lining were bolted together for checking purposes, and the actual circumference, measured with a steel tape, came within three-thirty-seconds of an inch of the theoretical circumference. The segments are erected so as to break joints, the key being on opposite sides of the crown in alternate rings, but the stiffeners will be in line.

Segment Joints

The joints between segments and rings, of which there will be about 240,000 linear feet, must be made water-tight. When bolts sufficient to secure water-tightness in the joints had been provided for, it was found that there were enough to carry the stresses. The holes will be seven-eighths inch for three-quarters inch diameter bolts. The specifications provide that abutting surfaces of the segments shall be covered with roofer's putty to insure that the joints will not leak.

Erecting the lining so as to break the longitudinal joints stiffens the lining because the cross joints are spliced by the adjacent segments. This has not always been done in the past. For instance, the Blackwall tunnel under the Thames River, 27 feet outside diameter, was built with continuous longitudinal joints.

Function of Steel Lining

The steel lining is primarily for construction purposes, as the permanent tunnel ring is of reinforced concrete. The functions of the steel lining are to keep out the earth and brace the tunnel, thus replacing the timbering used before the development of the shield method, to keep the tunnel dry, and to form an abutment against which the shield jacks can act to push the shield ahead. If it is assumed that the stiffeners take all the jack thrust, then the full capacity of the jacks if ever reached will produce about 23,000 pounds per square inch compression in them.

Stresses in Lining

One of the principal stresses in a tunnel lining is the ring compression, caused mainly by the crown load. This lining was designed for a crown pressure of 5,700 pounds per square foot, obtained by adding together the weight of 50 feet of salt water and the weight of 20 feet of clay, assumed to weigh 125 pounds per cubic foot. This assumed load is equal to any load on the land portions under buildings. The clay through which the old East Boston tunnel was driven was found to weigh 120 pounds per cubic foot. To find the ring compression, the crown pressure is multiplied by the radius of the lining, giving about 88,300 pounds per foot of tunnel.

It will be noticed that no allowance has been made for the arching effect of the earth over the tunnel. It does not seem safe to make any such reduction. At Detroit, the arching value of the ground across the tunnel was not sufficient to sustain the vertical load. Also, the experiments of Dean Anson Marston on culverts seem to show that little reduction in the crown load occurs until the depth of earth over the culvert is somewhat greater than the diameter of the culvert. His experiments further show a much more uniform distribution of external pressure around the ring of a flexible corrugated iron culvert than of a rigid concrete or cast-iron one, which leads to the conclusion that flexibility in a tunnel lining ought to be a desirable property. This lining is not so deep as the heavy type lining of the Detroit–Canada tunnel, but has a little more metal in the cross section. By the use of a special angle which we have designed the metal is so arranged that the neutral axis is much nearer the center of the section than in the case of the Detroit lining, where standard angles were used.

A very important feature in the construction of shield-driven tunnels in firm ground is the grouting or filling the space left by the shield just outside the lining.

Ring Clearance and Distortion

As previously stated, the lining is erected within the shield. Naturally, there must be some clearance between the lining and the shield. In this tunnel the clearance will be about 1 inch. The skin plate of the shield is 2¾ inches thick, so that when the shield moves ahead, a space of about 3¾ inches remains all around the lining between it and the hole left by the shield in the ground. This is the space that should be tightly filled as soon as possible. If, through inexperience, it is not filled, when the crown load comes upon the lining, the crown sinks and the horizontal diameter of the tunnel lengthens. The distortion of the lining may cause it to bind in the shield, and in any case makes the erection of the rings difficult. It would be, of course, impossible to make a lining so strong that it would not distort slightly under the action of the vertical loads. The contract for Section A, however, limits this allowable distortion to 1 inch at the crown, and requires that the contractor use tie rods or compressed air to prevent further distortion. The practical way of limiting the bending moments in the lining and preventing large distortions in it is to put something solid between the lining and the ground before any appreciable distortion has taken place, so that when the weight of the overlay comes upon the crown, the deflection of the ring will call into action the resistance of the ground.

Grouting

In this tunnel the specifications provide that "the space between the steel lining and the soil surrounding the tunnel shall be filled by pumping in, under pressure, dry grout, consisting of one part of cement to four parts of sand, and such water as the engineer may prescribe." "The grouting shall follow the shield closely, at no time being at a greater distance than the third ring from the shield." "After the steel ring is completed and the compressed air is removed, liquid neat cement grout made from high early strength cement shall be forced into the grout pipes. . . . This grout shall completely fill the voids in the grout previously placed. Grouting shall be commenced at the bottom of a ring or section and shall proceed uniformly upward unless some other order of grouting is directed or permitted by the engineer."

Moments in Ring

In considering the moments in the ring it is necessary to distinguish between tunnels built in firm ground, where a void is left around the lining by the advance of the shield, and those in soft ground, where the soil closes in around the lining, leaving no void to be filled by grout.

The deflections of the linings are of opposite sign in the two cases. The lining in soft ground, such as Hudson River silt, when first constructed, deflects in such a way that the vertical diameter is increased and the horizontal diameter is decreased. In the firm ground tunnel, as previously stated, the deflections are just the opposite. This points to a theory that it is the active earth pressure which presses over much of the circumference of the soft ground tunnel, whereas it is passive earth pressure, developed by the pressure of the lining against the ground, which acts over much of the outside of the firm ground tunnel.

Loading and Thrusts

This Boston tunnel is expected to be in firm ground throughout. Nothing like Hudson River silt is expected to be encountered. The grout will bed the lining nicely in the ground. A ring, after the shield has advanced beyond it, will be subjected to the crown load acting over the whole or a part of the portion above the springing line. The part against which the crown load bears will be a steel arch, and will deflect as such, that is, the crown will drop slightly within the limits mentioned above. The vertical component of the arch thrust will be wholly taken by the lower part of the ring. The horizontal thrust will be taken by the ground. The part of the ring not loaded with the active pressure of the crown load is a curved member with an axial load equal to the crown thrust of the arch and a lateral load equal at any point to the passive earth pressure. There is no active force on this part of the ring except the axial load. The effect of the axial load, of course, is to tend to make the curved segments bend outward, and this tendency is resisted by the ground. The net result of all this is to create radial pressures which are nearly uniform all around the ring. If the pressures were uniform and radial, and acted on a truly circular ring, of course there would be no moment in the ring. It is probable that there is some. The rings actually distort a little. In the Detroit–Canada tunnel at the start there was a 3 or 4 inch shortening of the vertical diameter. After the workmen became more experienced, and under compressed air, the drop at the crown was reduced to 1 inch, which as before is the maximum allowed in this tunnel.

Nothing has been said about stress diagrams so far. In the case of a tunnel in firm ground they seem to have very little value. Applying active earth pressures, according to Rankine's formula, even with low values of the angle of internal friction, gives stresses that appear excessive.

MOMENTS

The moments in a tunnel ring where the grouting is well done cannot be large. The Dorchester tunnel, 24 feet 2 inches outside diameter, was built with a primary lining of wood 9 inches deep. The segments were rather short, and only two one-half inch drift bolts connected each segment to the ring previously erected. Another instance is furnished by the single-track railroad tunnel built for the Grand Trunk under the St. Clair River and completed in 1890, which has an external diameter of 21 feet, and the distance from the top of the tunnel to the water level is 55 feet. The ground through which it passes is a soft clay. The lining consists of cast-iron segments 5 feet long, 18 inches wide and only 7 inches deep. The cross joints were packed with a thin strip of wood and are in line. Four seven-eighths inch diameter bolts pass through the cross joints near the center of depth.

Grout was poured, not forced, through the grout holes below the spring line of the tunnel, no grouting being done on the upper half of the lining. No difficulties with the lining are spoken of in the articles describing the construction of the tunnel. Such linings could be successfully used only if the moments were small.

The only experimental work which would appear even remotely related to tunnel linings is that for determining the loads on culverts, some of the results of which have been given.

The moments in the ring, then, cannot be found, due to the uncertainty of the exterior loading. The late Mr. C. M. Holland, chief engineer of the New York traffic tunnel, in a discussion on the subject of tunnel linings, characterized certain elaborate attempts to find the exact stresses as mental gymnastics.

In the 1921 report of the Public Commission, which built the Holland tunnel, there are several stress diagrams of the lining, based on different assumptions as to the angle of internal friction of the silt, but a close reading of that report and other reports of that commission fails to disclose any statement as to what the engineers believed were the actual stresses in the lining.

Various Tunnel Linings

Tunnel linings have been made of wood, brick and plain concrete. The majority of shield-driven tunnels have been lined with cast iron. Not one has failed. The Detroit–Canada tunnel has a steel lining in the shield-driven parts and is 8 inches larger in outside diameter than the Boston tunnel will be. It was driven through a stiff gray clay, presumably much like the Boston clay. It is jointed in the same manner as the Boston lining. The maker of both linings and the method of manufacture will be the same. The Boston lining will be a little heavier than the Detroit lining, which, as stated before, met all requirements.

Compressed Air in Construction

A large part of the shield-driven part of the Boston tunnel will probably be built under compressed air, that is, the excavation will be done and the steel lining will be erected under an air pressure of possibly 28 pounds per square inch. The influence of compressed air on the lining will be to diminish the ring compression. Under an air pressure of say 20 pounds per square inch, the ring compression will be reduced to about half that under normal air.

Under the figured ring compression, the stress in the lining will be about 8,800 pounds per square inch under normal air, and 4,400 pounds per square inch under 20 pounds per square inch compressed air.

It is expected that in years to come the steel lining may deteriorate although protected by the cement grout.

Reinforced Concrete Lining

This, however, is unimportant, as the tunnel itself is built of reinforced concrete 18 inches in thickness, and is a monolithic ring practically indestructible.

The concrete lining was designed for the same loads as in the case of the steel lining. Making due allowance for that part of the concrete which might be ineffective on account of being between parts of the steel lining, the ring compression figures about 500 pounds per square inch. The inner face will be reinforced and will be capable of taking as much moment as the steel lining.

Floor and Ceiling of Tunnel

The floor of the tunnel will be supported by steel beams 5 feet apart spanning the fresh air duct. The concrete slab will be thick enough to cover the beams and provide a smooth top for the duct in order to make the air friction a minimum.

The ceiling of the roadway is a thin concrete slab supported in the middle by non-corrodable metal hangers.

A large amount of work has been done on the plans for the ventilation buildings, the box sections, inclines and plazas at each end of the tunnel, and the mechanical equipment, but many other problems relating to the tunnel are now being worked out.

The entire project is under the direction of the Boston Transit Department. The commissioners are Colonel Thomas F. Sullivan, chairman, Mr. Nathan F. Heller and Mr. Arthur B. Corbett, associate commissioners. The chief engineer is Mr. Ernest R. Springer. The designing engineer is Mr. Leonard B. Howe. The contractor for Section A is the Silas Mason Company, Inc.

MOISTURE PENETRATION IN EXTERIOR WALLS

By H. A. Gray*

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Here are presented some of the data assembled during a recent investigation of the factors affecting the construction of a satisfactory exterior masonry wall. Only those portions of the exterior wall which are above ground are considered, and particular consideration is given to brick-faced construction, including design, the choice of materials, and workmanship.

I. Functions of Exterior Walls

Exterior walls to function satisfactorily should be —

(*a*) structurally sufficient for all loads imposed upon them and for all conditions incident to the occupancy of the building which they enclose,

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(*b*) stable against premature collapse under exposure to fire, and adequate to provide support and heat insulation to prevent undue loss,

(*c*) sufficiently resistant to moisture penetration to insure —

first, the permanency of the wall itself and all structural members which may be built into the wall or supported by it,

second, the maintenance of sanitary and healthful living or working conditions,

third, the protection of all goods or furniture, and the preservation of all interior decorations and fixtures, and

fourth, the maintenance of the satisfactory appearance of exposed wall surfaces..

II. Moisture Penetration Resistance — How Effected

The penetration of moisture through an exterior wall may be prevented by providing an impervious skin or envelope. This method would appear to be the simplest and most straightforward were it not for the difficulty or impossibility of constructing this impervious shell. Breaks, cracks, joints and other openings in the surface are impracticable if not impossible to avoid, and moisture which enters through these openings accumulates until damage occurs, as the impervious skin does not permit sufficiently rapid evaporation of the moisture which has entered the interior of the wall. Accordingly, an exterior wall having a high capacity for the exudation of moisture during dry intervals is much more satisfactory than a wall which does not permit breathing or evaporation of the absorbed or entrapped moisture because of a slowly pervious skin.

Because of the limitations in constructing and maintaining an impervious surface exposed to the weather, the ideal wall is one which has a relatively slow rate of water penetration, so that, during the period of maximum storm, dampness does not appear on the inside face of the wall; and one which, at the same time, has a high capacity to evaporate or exude the absorbed moisture from the exterior face of the wall during the dry period.

III. Elements of the Wall

In considering in detail the action of weather on the exterior of buildings, and the properties of the various materials used in exterior wall construction, it is convenient to consider separately the various elements of the wall. For this purpose they may be classified as follows:

1. Body of the wall.
2. Sections of the wall occurring at floor levels where the floor framing is either supported by, built into, or enclosed by, the normal section of the wall.
3. Parapets and details at juncture with the roof.
4. Construction at openings, such as windows, doors, conductor heads, scuppers, etc.
5. Projecting members, such as copings, cornices, belt courses, corbels, etc.
6. Base or ground course.

IV. Body of the Wall

Reserving for later discussion all questions of choice of materials and workmanship, a wall of 13-inch solid brickwork, constructed as follows, is generally satisfactory:

(*a*) All brick laid with a full bed of mortar.

(*b*) Inside face of the facing brick, and the ends of all header brick from the facing, thoroughly pargeted with mortar.

(*c*) All vertical joints in the brickwork completely filled.

(*d*) Mortar joints at the exterior face of the wall compacted with a convex tool, and mortar joints at the interior face of the wall struck smooth and flush with the brickwork.

(*e*) Damp-proofing mastic applied to the inside face of the wall. (Plaster may be applied directly to this mastic damp-proofing.)

1. Properties of Materials, Details of Design, Workmanship

In order that the body of the exterior wall may meet the requirements of an ideal wall, and function satisfactorily in resisting moisture penetration, it is extremely important that careful attention be given to the selection of the materials going into the wall; to the proper proportioning and manipulation of these materials in the construction of the wall; and to the adequate control of workmanship during construction.

A. *Brick Units*

Weathering. — It is important that the brick units should weather satisfactorily. Weathering action may be classified as chemical attack due to the leaching or solvent action of rain or absorbed moisture; the action of frost; volume changes due to variation in temperature or moisture content; and the attack of plant life.

Of these, the last is largely a question of maintenance. The effects of volume changes, which will be discussed later, are important only when appreciable differences in magnitude of volume change occur between materials laid up in close contact.

Frost action is generally the most active weathering agent. It deserves careful and serious consideration, particularly in those portions of the world where the average temperature for prolonged periods is at or near 32° F., and where, during this period, rains and snows are of frequent occurrence, for under such conditions many alternations of freezing and thawing are to be expected.

The change in state from water to ice is accompanied by an increase in volume of approximately 10 per cent. Space for this expansion must be provided else the tremendous pressures developed may be greater than the strength of the masonry unit, and, upon repetition, progressive fracture and disintegration of the unit may occur. Space for the expansion of water during freezing may be afforded by the elasticity of the material (not the case in masonry units) or by adjacent unoccupied pore space.

The softer grades of brick, usually underburned, and called "salmons," are known to have unsatisfactory weathering resistance. Total absorption is not necessarily a guide to the weathering qualities of masonry units. For bricks made of the same raw material and by the same method, total absorption may be a satisfactory guide for relative weathering characteristics, but with a variation of these conditions its use is likely to mislead.

At present there is probably no satisfactory method by which to predetermine accurately and rapidly the relative weathering characteristics of bricks. One of the most useful guides is Schurecht's ratio. This is the ratio of the water absorption for forty-eight hours' cold immersion to the absorption for five hours' boiling. A Schurecht ratio of 0.85 may be suggested as the general border line between good and bad weathering bricks. This separation, however, is not universal, as there are exceptions due to the particular characteristics of certain raw materials. A Schurecht ratio above 0.85 may indicate the unsatisfactory weathering characteristics of the brick in question, and acceptance of such brick should be based either on the satisfactory performance of similar brick, or on the results of more exacting alternate freezing and thawing tests. On the other hand, a Schurecht ratio below 0.85 does not necessarily assure satisfactory weathering characteristics.

The United States government "Master Specification for Brick, Clay, Common," promulgated July 11, 1927, states that, "In cases of doubt, and where the time and equipment are available, acceptance in point of weathering resistance can be based on ability to withstand 100 alternations of freezing and thawing conducted according to generally accepted laboratory procedure. Failure is to be considered as reached when the samples are cracked or show superficial disintegration or spalling, with loss of weight of more than 5 per cent of the initial dry weight."

This freezing and thawing test involves some time and considerable equipment. Research is being carried on to evolve an accurate, rapid and conclusive laboratory test for the relative weathering characteristics of masonry units.

Permeability. — Next to weathering, permeability is probably the most important characteristic to be considered in the choice of a brick unit.

As is the case in weathering, absorption is the principal point of attack, but total absorption alone is likely to be irrelevant and misleading. Among bricks made from the same raw materials and by the same method, the more highly absorbent bricks show a higher rate of absorption, but this relationship would not necessarily hold if the bricks were made from different raw materials or by a different method. For example, bricks made by the dry-press process absorb water far more rapidly than do bricks of other methods of manufacture, even when the same raw materials have been used. The rate of absorption is, in general, the controlling factor in any consideration of the permeability of brick units.

If a brick has a low rate of absorption, this property, considered in a negative sense, indicates that the same unit will permit but a slow evaporation of moisture from its surface. Although a brick with a low rate of absorption and a low total absorption is, of itself, a barrier to moisture penetration, it lays up so poorly in the wall during construction that the masonry may not be properly bonded, and many passages for the penetration of moisture into the interior of the wall may be provided by cracks or openings between the mortar and the bricks.

The penetration of water through a masonry wall is, to a large extent, controlled by the quality of the bond between the brick units and the mortar. The rate of absorption in the unit has a marked effect on the bond between the brick and the mortar. Poor bond, which, to the extent of the absorption of the brick, is more a function of the masonry unit than of the mortar, is due to not wetting, or underwetting, a rapidly absorbent brick, or to laying a non-absorbent brick too wet. The ideal masonry unit from a construction point of view is one which can be laid satisfactorily by the average mason with a normal mortar in the air-dry condition in which it is received on the job. Further information is being sought on the limits for the rate of absorption which give these desired "suction" characteristics.

It would be a distinct service to the construction industry if the original investigators and research workers on brick masonry were to define a rapid field test which would indicate what units, if unwetted, would lay up properly in the wall, and would bond satisfactorily with a normal mortar.

Granting the importance of the design of the mortar mix as a factor in producing a strong and permanent bond between the mortar and the brick unit, the fact remains that, to be satisfactory from the point of view of the brick mason, the suction of the brick unit should vary only between rather definite limits.

The unavoidable lack of adequate control and réfinement in all field efforts to temper by wetting the suction of rapidly absorptive brick, and the necessity for omitting this procedure in freezing weather, indicates clearly the advantages of selecting a brick unit which has the desired suction characteristics when it is laid dry.

Much trouble arises in exterior brickwork from the use of bricks which have an extremely low total absorption and a low rate of absorption. Such bricks are known to the mason as "floaters." Due to the absence of any suction, the mortar remains plastic for a considerable period, making the newly built wall unstable. Sometimes, to correct this, the mortar is stiffened by sprinkling the mortar bed with a mixture of sand and cement before the next course is laid. This practice destroys the bond between the mortar and the masonry unit, and should not be permitted. Inadequate suction also makes difficult the proper filling of vertical joints, as the mortar, if at all plastic, has a tendency to slump down in the joint and settle away from the brick above, leaving openings in the interior of the wall through which moisture may penetrate or water may pass.

Mr. J. W. McBurney, Research Associate of the Common Brick Manufacturers' Association at the Bureau of Standards, Washington, D. C., has developed a method of test which determines in a qualitative way the suction which may be expected in any particular brick: a circle approximately two centimeters in diameter is marked with a wax crayon on the face of the brick to be tested; into this circle, one milliliter of water is delivered from a pipette, and the length of time required for the absorption of the water is then noted. A more extended comparison of this method with the conventional one of noting the absorption after partial immersion in one-eighth inch of water for various time periods, or with the absorption after complete immersion, may establish a relationship which will give to the user of brick the desired information concerning suction characteristics.

Stiff-mud, side-cut shale brick, in general, have a much slower rate of absorption than burned clay units of other methods of manufacture. It may be interesting to note that approximately 20 per cent of all common brick and approximately 80 per cent of all face brick are manufactured from shale.

The absorption characteristics of sand-lime brick compare favorably with those of burned clay units. Taken as a class, sand-lime brick is slowly absorbent, and, when well made, the rates of absorption vary relatively little from the average for the type. The fairly large total absorption gives a unit of considerable capacity for water, and the moderate rate of absorption insures a fair rate of exudation of moisture during the dry portion of the weather cycle.

Efflorescence. — The amount of water-soluble material contained in the masonry unit is a factor which indicates fairly well the tendency of the unit to effloresce. Mr. L. A. Palmer, Research Associate of the American Face Brick Association, Bureau of Standards, has stated: "If a brick contains 0.05 per cent or less of water-soluble sulphuric anhydride in its outer one-eighth inch of exposed surface, it is not apt to contribute to the development of efflorescence on a wall under conditions most favorable for such development." *

Unless careful attention is given to the choice of raw materials and to the control of the firing of the brick, the water-soluble sulphuric anhydride content may vary greatly. Any chemical laboratory can apply the necessary tests to determine the water-soluble sulphuric anhydride content of brick from a particular source.

The American Face Brick Association has made an important study of the method of controlling the soluble sulphuric anhydride content of its product, and has made available the findings of Mr. Palmer to the effect that the addition of barium carbonate to the clay, control of the burning temperatures, and regulation of the amount of air admitted to the kiln, materially lessens the tendency of the product to effloresce. A qualitative test proposed by Mr. Palmer to determine efflorescent tendencies is to stand the brick on end in a shallow pan containing about one inch of distilled water, adding water from time to time to replenish loss from evaporation. Efflorescence will develop on the air-exposed surfaces if there are soluble salts in the brick. Soluble salts in such an amount as to cause serious efflorescence in a wall will usually show a deposit on the bricks in less than one month.

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* "Cause and Prevention of Kiln and Dry-House Scum and of Efflorescence on Face-Brick Walls," by L. A. Palmer, p. 628. (Technologic Papers of the Bureau of Standards, No. 370. June 19, 1928.)

Efflorescence may be caused by the leaching of the soluble salts through the mortar or backup materials to the face of the wall. Therefore the amount of water-soluble salts in these elements of the wall should be carefully controlled.

B. *Mortar*

To be ideal, mortar used in the laying of exterior wall masonry must meet many exacting requirements. It is true that the design of a mortar mix is a compromise, because any effort to improve one desirable characteristic usually results in a loss of effectiveness in one or more of its other essential properties. Thus, the possible range of proportions of ingredients for a satisfactory mortar is quite limited.

The essential characteristics of mortar, in their order of relative importance, are probably as follows: plasticity, volume change, content of water-soluble material, and strength.

A very satisfactory mortar, combining in a large measure the desirable characteristics controlled by the proportions of cement, lime and sand, is composed of one part cement, one part lime putty, and six parts sand, all measured by volume.

As the quality of mortar depends to a large extent on the characteristics of its ingredients, any consideration of mortar must include a discussion of the essential raw materials which enter into its composition.

Essential Ingredients. — The cement, preferably, should be a standard Portland cement meeting the requirements of the current A. S. T. M. Specification. It may be noted here that the usual water-soluble sulphuric anhydride content of standard Portland cement is about 1½ per cent. There is authority for the statement that all this does not appear as a water-soluble salt after the normal hydration of the cement.

Lime for brick mortar is satisfactory if it conforms to the A. S. T. M. "Specification for Hydrated Lime for Structural Purposes" (C 6–31), or to the A. S. T. M. "Specification for Quick Lime for Structural Purposes" (C 5–26).

For best results, lime for brick mortar should always be used in the form of putty. The method of slaking quicklime is an important factor in determining the quality of the resulting putty, and as different limes vary considerably in the way in which they behave with water, the operation of slaking should be carefully supervised so as to avoid either the flooding or overburning of the lime. Overburned lime has been known to delay proper hydration from six months to two years. The phenomenon of delayed hydration is sometimes noted in wall plaster where popping or blistering occurs. The adequate aging of putty is helpful in producing a thorough hydration of the lime.

Research has developed the fact that the delayed hydration of the high magnesium limes is accompanied by swelling. There may be some basis for choosing a high calcium lime, which largely avoids this delayed hydration effect. In such a high calcium lime the magnesium oxide would not exceed 2½ per cent of the nonvolatile portion.

The average water-soluble sulphuric anhydride content in lime, meeting the above Specifications, is approximately 0.5 per cent.

The A. S. T. M. "Specification for Sand for Use in Lime Plaster" (C 66–31 T) represents, probably, the best thought on sand suitable for brick mortar. The studies supporting this Specification involved the collection of data on many typical sands from all over the United States. The limits in this Specification are fairly broad, yet about one-third of the sands studied failed to comply in all respects with these limitations. A proper grading between the fine and the coarse grains in a mortar sand should be given consideration in choosing the source of supply for a particular job, as this characteristic affects to some extent the important items of plasticity and volume change as well as the economy of cementing materials. Some sands contain water-soluble salts; therefore suitable tests should be made to avoid the use of such sands where the continued good appearance of exterior masonry is of importance.

Water used for the mortar mix may, in some localities, contribute to efflorescence. The appearance presented by structures in which the water in question has been used may be taken as a guide. The usual criterion of potability is sufficient for the acceptance of water, except where superior medicinal properties may be claimed for it. The available supply, if not of the best, usually presents the problem of how it may best be used, rather than of providing one of better quality. In certain cases this question may merit the advice of a consulting chemist.

The careful selection of all materials entering into exterior wall construction to insure the absence or a minimum of water-soluble salts, particularly those present as water-soluble sulphuric anhydride, is a very important step toward securing a non-efflorescent wall.

Design of the Mortar Mix. — The problem of design of the mortar mix involves a balance between a high cement content characterized by high strength, short time of set, fair workability and some shrinkage; a high lime content, which is less strong, slower in set, more workable, but having greater shrinkage; and a high sand content, which gives low shrinkage, low strength and poor workability.

The paper, "Cement-Lime Mortars," by H. V. Johnson, of the Bureau of Standards, is one of the most complete studies of this subject available. It should be noted that Mr. Johnson's study treats of wet mortars and the period closely following their final set or hardening. Mr. Palmer, in "Volume Changes in Brick Masonry Materials," has made an important contribution to our information concerning the behavior of various mortars over extended periods of time and under different exposures.

A straight Portland cement mortar works short and has not sufficient plasticity to allow easy handling by the average mason without special effort on his part.

The use of lime in cement mortar reduces the cost of the resulting mixture, as, for a given plasticity, the more lime substituted for cement, the larger the total amount of sand the mortar will carry; or, from the mason's point of view, if the total sand is held constant, the substitution of lime for cement improves the plasticity. The use of lime increases the time of set by periods up to four hours longer than that of a straight cement mortar. However, these and other effects contributed by lime are not directly proportional to the ratio of lime to cement used in the mortar mix.

Mr. Palmer shows that the shrinkage during the early hardening of 1:3 lime mortar ranges from one and one-quarter to five times that of 1:3 Portland cement mortar, depending upon the limes or Portland cements compared, with median values of two and one-half to three and one-half times. Mr. Palmer also shows that alternate wetting and drying of these Portland cement mortars induces a linear change of about one-third the value of their shrinkage during early hardening, whereas with lime mortars the alternate wetting and drying causes an almost negligible change in length.

A high sand content in mortar reduces its tendency to volume change, but accompanying this desirable effect are the undesirable characteristics of low strength and poor workability.

Where a high premium is placed on small initial shrinkage, and where the extra labor cost may be justified, shrinkage may be reduced by the use of a uniformly graded sand, and by partial hydration of the cement before it is used in the mortar mix. The cement is hydrated by adding to all the dry materials, after they have been placed in the mixer, only sufficient water to produce damp-earth moistness, and by laying aside this dry mortar for a short time before it is remixed with the other ingredients necessary to produce the required mix. Partial hydration should not be attempted if a water repellent is used in the mortar.

It should be noted that, although shrinkage of mortar in the bed joints during hardening is not desirable, it is not necessarily a factor in allowing moisture penetration through these joints. In the bed joints, however, differences in magnitude of volume change between the mortar and the masonry units, subsequent to the hardening of the mortar, tend to break down the bond between the two materials, and to render the mass of the wall more liable to moisture penetration. Shrinkage of the mortar after hardening also tends to destroy the bond, and to form transverse cracks in the mortar joints.

Vertical joints, which are usually the worst offenders, are directly affected by shrinkage and by other volume changes in the mortar both during and subsequent to hardening.

Accordingly, the ideal mortar should be designed to produce a minimum volume change throughout the entire life of the mortar, rather than merely throughout the period either before or after hardening.

Mortar which has been mixed for two and one-half or three hours can be safely used, provided it has not set or hardened to such an extent that water must be added, and provided it has been remixed frequently without the addition of water. Retempering of mortar does not improve any of its desirable characteristics, and should be forbidden unless it is controlled with extreme care. Preferably, it should be permitted only for interior non-bearing masonry. Excess water in mortar permits easier application, but increases the porosity and shrinkage of mortar, and thus allows a more rapid leaching out of any soluble salts that may be present in the mortar or backup materials.

The thorough mixing of mortar is advantageous, and for this reason, whether or not machine mixing is used, mortar should be mixed sufficiently to develop its inherent plasticity and workability.

Lime should be omitted from mortars which are exposed to the action of sea or ground waters. A straight lime mortar is much weaker than a Portland cement mortar, and should not be used for construction subject to excessive dampness or to high temperatures, for under these conditions it loses its binding properties. It has been observed that in manufacturing centers there is a sufficient concentration of sulphur dioxide in the atmosphere to leach out a straight lime mortar under certain conditions of wetness. Snow water in certain localities has been found, at times, to contain a relatively high percentage of sulphuric anhydride, which rapidly disintegrates a lime mortar.

From practical considerations it is desirable that but one mortar (except where mortar color is specified) be used on any one job; that is, the mortar used for the face brick should be used for the backup materials.

Mortar color detracts from rather than adds to the desirable properties of a mortar, and, in general, it is not recommended. Where a mortar color is absolutely necessary because of architectural considerations, high-grade mineral pigments should be used. Mixing of pigments in the field should be permitted only if a satisfactory factory-made, colored Portland cement cannot be obtained.

Volume Changes. — Beyond the initial shrinkage of the mortar, there are other volume changes in the materials used in exterior wall construction which must be recognized.

Variations in degree of saturation alter the volume of building materials. The effect of these changes in volume is similar to that caused by changes of temperature. Capillary force tends to maintain moisture equilibrium, but as movements of water take place slowly, internal stresses are unavoidable. Surface hair cracks, particularly in concrete and cast stone, are evidence of this action.

Following is a table of temperature, swelling and shrinking coefficients for certain materials used in exterior wall construction (from Kreüger, Transactions, Royal Swedish Institute, 1923). The amount of swelling refers to three or four weeks' immersion in water; the shrinking refers to the subsequent parching.

MATERIAL	Coefficient of Expansion per 10° Centigrade	Swelling	Shrinking
Brickwork	.00005 to .00006	.00010 to .00015	.00012 to .00020
Cement mortar 1:3 . .	–	.00020 to .00040	.00030 to .00050
Concrete	.00010 to .00014	–	–
Granite	.00008 to .00011	.00006 to .00012	.00015 to .00018
Limestone	.00008 to .00010	.00013 to .00019	.00040 to .00050
Sandstone	.00013 to .00018	.00011 to .00053	.00017 to .00040

One of the important considerations in the question of bond between the masonry units and the mortar, as well as between the brickwork proper and metal or artificial stones, is the difference in magnitude of volume change due to temperature variation and moisture content. The preceding tabulation shows that, for temperature change, the coefficient of expansion for brickwork is less than that for other masonry materials used in wall construction. The same is true, in general, for swelling and shrinkage due to variation in moisture content. Cement mortar and concrete have magnitudes approximately twice that of brickwork, and the inertness to volume change of well-fired burned clay, considered alone, is generally known. These facts reveal the importance of masonry bond and the desirable objective of reducing the difference between these rates by using a properly designed brick mortar, and by doing everything possible to provide a strong and durable bond between the mortar and the masonry units.

It is obvious that the ideal mortar, after passing through its plastic state, should have a volume change which corresponds to that of the masonry units used. The problem of the research laboratory, the engineer and the builder is to determine how this ideal can be obtained.

An Admixture for Brick Mortar. — Where the proportions of the mortar ingredients are fairly definite and fixed, the water-soluble material may be controlled, and the volume change due to moisture content may be retarded by the use of an admixture as a water repellent.

The American Face Brick Association recommends the use of 2 per cent of calcium or ammonium stearate by weight of cement, to retard the leaching out of soluble salts in the face brick and mortar, and through the mortar from the backup materials. These stearates greatly increase the imperviousness of the mortar, and lessen the extent of moisture penetration. In this way they appreciably retard leaching action, and reduce volume change due to moisture content. They do not fill the pores in the mortar, but, by coating them, greatly reduce the capillary effect.

The normal breathing of a wall involves the passage of water vapor to the exposed surface. This fact raises a reasonable inquiry as to the effect of a water repellent used in the mortar. The reduced capillarity induced by the water repellent minimizes the penetration of water, but does not materially retard the exudation of water vapor.

One of the best methods of introducing a water repellent into brick mortar is the use of a Portland cement in which there has been incorporated at the mill a proper amount of calcium stearate. As a second choice, ammonium stearate may be added to brick mortar in the field. Ammonium stearate is a paste, and should be diluted to a creamy consistency by the addition of three parts of warm or hot water. This solution should be added to the mix with the other ingredients, using one gallon for each sack of cement. Where ammonium stearate is used, at least 8 per cent of hydrated lime by weight of cement should also be used in the mixture, to hold the water required for normal hydration in contact with the Portland cement. Otherwise, the water would not be available, due to the sealing of the pores by the stearate.

Both calcium stearate and ammonium stearate slightly retard the normal set of Portland cement, by reason of this pore-sealing action. A slightly greater retardation is noted with the use of ammonium stearate. Commercial calcium stearate contains about 80 per cent of hydrated lime, which is added to keep the compound in powder form. Ammonium stearate, a paste, contains about 20 per cent of stearic acid, which is rendered miscible by first dissolving it in alcohol and then treating with ammonia. The 2 per cent admixture recommended by the American Face Brick Association is undoubtedly based on the use of these commercial stearates.

As calcium stearate is a powder, extremely light and very difficult to moisten, it should be mixed dry with sand and cement. On account of this extra operation and the difficulties surrounding the thorough incorporation of the stearate in the mix, the field use of calcium stearate is not recommended.

As a third choice for a water repellent in brick mortar, some consideration may be given to the use of a "waterproof" lime. This product is too new to warrant any comment here, other than that, in the slaking process, with the accompanying heat, conditions are favorable for a thorough dispersion and combination of the stearate or other water repellent.

The information available as to the effect of stearates upon the strength and durability of the bond is not conclusive. Inasmuch as the durability of the bond between the brick and the mortar depends to a large extent upon the relative volume changes of the two materials due to moisture content, it seems a fair assumption that, if the penetration of the moisture were retarded, the durability of the bond would be to that extent increased.

Barium carbonate is sometimes proposed as a mortar admixture to render insoluble the mortar salts which cause efflorescence. Barium carbonate has no water repellent properties, and, in the absence of heat, it reacts very slowly in producing insoluble sulphates.

There are many admixtures on the market, the use of which, it is claimed, improves mortar plasticity, water repellency, water-tightness, and inertness to volume change. The same may be said of the several proprietary masonry cements. The presence of these admixtures and proprietary cements on the market is a recognition of the need for better masonry mortar. But does not the general use of improved mortar depend, rather, on the proper choice of essential ingredients and on the balanced design of the mix?

Workmanship. — In laying up exterior brickwork, even and complete bedding of the masonry units is extremely important, and the joints should be sufficiently thick to permit this. Tests show that joints up to three-eighths of an inch in thickness do not affect the strength of the wall. Vertical joints should be buttered and shoved, and this one item of workmanship, together with the complete pargeting of the inside face of the facing brick, is probably of first importance in obtaining construction which is resistant to moisture penetration.

One of the leading builders has it distinctly understood by special verbal instructions to the masons, at the start of each job, that failure to butter fully the vertical faces leading to exposed vertical joints, and to shove them into their proper positions, is sufficient cause for summary dismissal from the job. Careful supervision and the moral effect of enforcing the penalty of dismissal are the principal factors in securing superior workmanship.

Although special emphasis has been given here to vertical joints at the exposed surface of the wall, there is no question but that superior workmanship at this location, and possibly the development of good habits on the part of the brick mason, will result in better construction throughout the wall, and in increased resistance to moisture penetration.

By compacting, with a convex tool, the mortar joints at the exterior face of the wall, the mortar is made more dense, a surface finish is applied, and an improved bond is developed between the mortar and the brick. All these results tend to improve the resistance of the wall to moisture penetration.

By striking the mortar joints at the interior face of the wall smooth and flush with the brickwork, a proper surface is provided for the effective application of any damp-proofing materials.

The shortness of mortar required for the setting of bricks of relatively low surface absorption (with the attendant sagging of mortar in the vertical joints), failure to butter and shove exposed joints in the case of a normal brick and mortar, or careless workmanship in tapping the bricks to line, results in openings through the masonry which permit the rapid penetration of rain, especially when a storm is accompanied by wind. Bricks which have developed major cracks during the burning process should be looked upon with suspicion, for the same reason.

The "Stucco Investigations" of the Bureau of Standards, concluded in 1926, indicate that the minimum shrinkage occurs when an absorptive backing causes a stiffening of the mortar by the removal of excess water before chemical set occurs. This observation is unquestionably applicable to brick mortar, and is a further argument against masonry units with a very low rate of absorption. This same investigation on stucco confirms the previous statement that there is less shrinkage and map crazing when leaner mixtures are used.

In cold weather, the heating of both brick and mortar as a protection against freezing deserves consideration. In extremely cold weather, the wall should be protected by artificial heat and tarpaulins.

Efflorescence and staining of the wall may be controlled in many instances, or avoided, by protecting the wall from the weather during laying. It is an excellent rule never to leave the top of a wall uncovered or unprotected, as much harm may be done by the entry of storm water at this location. Canvas or tar paper is a suitable covering for the top of an unfinished wall, at the end of each day's work.

C. *Mastic Damp-proofing*

The mastic damp-proofing considered here has an asphalt base, and contains a mineral filler of asbestos fibers. It is usually applied cold, with a trowel, about one-eighth of an inch thick, on the inside face of the wall. The surface to which the mastic is applied should be dry. Special care must be taken in applying damp-proofing mastic at all interior and exterior corners, at pipe chases, and at all changes of materials, to insure continuity of the damp-proofing. Any pinholes or breaks in the mastic may eventually cause trouble. Pinholes or breaks in this membrane frequently permit such extensive moisture exudation that dissolved salts become concentrated at the location of the imperfections. These salts eventually crystallize, causing disintegration of the masonry and separation of the membrane from the wall, and blistering of the plaster which may or may not have been previously damaged by the moisture which has leaked through.

Due to increased land values and the use of steel framework, thick masonry walls are in many cases undesirable and unnecessary.

This limitation makes impracticable the use of sufficient thickness of wall masonry to protect an interior against moisture under severely adverse conditions.

Where, in fulfilling its function, a moisture barrier must withstand an appreciable hydrostatic head, either it must be backed up by a sufficient structural support, or must have inherent bond to a strong forewall. These severe conditions, however, do not apply to the mastic damp-proofing under consideration. An exterior wall which is otherwise satisfactory would certainly not have passages which would admit direct wind pressure over sufficient area to make wind pressure an essential factor.. No authority can be found to indicate that capillary forces exert appreciable pressures against such a mastic.

Apparently, no standard specifications are available for mastic damp-proofing. Under these circumstances, one must rely upon the knowledge and reputation of the manufacturer from whom the mastic is purchased, and its application should be by or under the control of the manufacturer. Research data leading to standard specifications for mastic damp-proofing and to its method of application would be of convenience to the building industry.

The applied mastic should have sufficient body to span the small cracks which may develop in a masonry wall, to prevent the possibility of pinhole passages, and to insure reasonable permanence of the mastic. The conditions which cause the deterioration of asphalt used on walls, as here proposed, are much less severe than in a roof exposure, because the asphalt is protected from direct sunlight and the wash of rain water. However, even in the latter location, asphalt is known to give very satisfactory results.

Under certain conditions, because of their shrinkage tendencies, emulsified asphalts applied to the interior faces of exterior walls are apt to tear and to provide only an imperfect barrier. The same is likely to be true of inferior grades of asphalt mastic.

In addition to serving as a barrier to moisture penetration from the exterior of the building, the use of mastic damp-proofing on the interior walls of humid rooms prevents the continuous flow of moisture from the inside to the outside of such walls, thus avoiding the development of stains or efflorescence.

D. *The Exterior Surface*

The capillary action in the absorbent brick and mortar, which is responsible for the penetration of the moisture, is not appreciably affected by wind pressure. Wind, however, is an important element in driving moisture through cracks in the mortar joints or through openings between the brick and mortar where the bond is broken. During a rainstorm, wind materially increases the volume of water coming in contact with the windward surfaces of the walls. However, water passing over the wall surface at any particular period in the exposure cycle, in excess of the rate of moisture penetration of the wall at that moment, does not aggravate the exposure.

As the function of an exterior wall is to retard the absorption or penetration of moisture from the exterior surface, and to exude or evaporate the moisture from this same surface, any barrier to the passage of moisture from the interior of the wall to the surface through which it must be evaporated is objectionable. Whatever their cause, cracks admit moisture to the interior of a wall, and, once in the wall, moisture tends to distribute itself uniformly. It has already been pointed out that impervious brick units are barriers to the exudation of moisture, and that, with their use, the moisture content of the interior of a wall is likely to be cumulative. This statement also holds for surface waterproofings used on the exposed face of exterior walls. Such colorless waterproofings do not effectively seal the cracks in the wall, and water entering through these openings is barred from normal evaporation through the average surface of the wall.

The ideal objective for an exterior wall is homogeneity, in so far as the retardation of moisture absorption and its rapid exudation are concerned. Imperfect barriers to the penetration of moisture, such as surface waterproofings and impervious bricks, are likely to admit more moisture through imperfections than can be exuded during the dry period.

On account of these factors, the waterproofing or damp-proofing of any wall on both sides is extremely inadvisable. Such procedure is safe only when the enclosing envelope is also vaporproof — a practical impossibility in building construction, especially where good appearance is a factor.

Although apart from the subject of moisture penetration, a word of caution about the use of too strong an acid in washing down a completed exterior wall may be appropriate here. Where this is permitted, the lime in the mortar becomes burned, and the wall loses much of its attractiveness. A concentration not greater than one part of hydrochloric acid to ten parts of water is recommended; this to be followed immediately by a thorough washing down with a hose. Straight vinegar is also recommended, on good authority, for this purpose.

2. OTHER METHODS OF BACKING

Systems are in current use for the construction of exterior walls which are lighter in weight than the solid wall previously described, and the argument of economy to be gained in the way of supporting framework and foundations is, of course, a strong one. A further argument for these other methods of backing is the economy afforded in wall construction by the greater amount of wall laid in a unit of time, due to the large size of the backup units. With the larger unit, however, the filling of vertical joints becomes a serious and difficult problem. Because of the large hollow spaces in the backup masonry, the volume of absorbent material available to retard the penetration of moisture is greatly reduced. The result is that, with the same total moisture entering a solid wall and a wall of hollow backup material, free moisture occurs much sooner in the second case, owing to the earlier complete saturation of the masonry.

Hollow backup units, integral with the body of the wall, furnish, to a limited extent, a substitute for furring. This may be both satisfactory and economical, provided all the other functions of the wall which affect moisture penetration are adequately fulfilled.

The considerations which control the probable weathering resistance of burned clay bricks also apply directly to burned clay backup tile used in walls exposed to weather. In addition to burned clay terra cotta backing, cement tile and gypsum tile are used to some extent. In many instances, satisfactory walls result from the use of these other methods of backing, with or without the application of damp-proofing mastic. The above discussion does not necessarily disapprove the use of these other methods of backing under any particular set of conditions, but, rather, it supports the idea that a superior wall can be built of solid brickwork.

The design of an exterior wall in which air spaces or vertical channels are provided for the purpose of trapping moisture and releasing it before damage occurs cannot be considered a solution of the problem of moisture penetration, as it presumes entry into the wall of appreciable quantities of liquid water, and places difficulties in the way of securing a bond between the facing veneer and the main body of the backing that will give adequate strength, and, at the same time, prevent the passage of moisture to the backing itself. This vaulted wall presupposes suitable weep holes above the impervious membranes at the spandrel beam levels. Such weep holes tend to cause an infiltration and circulation of air into the body of the wall, thereby creating a more serious exposure condition than exists with a solid masonry wall.

Quite frequently the use of damp-proofing paint is specified as a substitute for the damp-proofing mastic previously described. The use of a damp-proofing paint is less satisfactory because of the number of coats required to insure a perfect job, and because of the tendency of moisture or temperature volume changes in the wall, or structural cracks to destroy its effectiveness.

Emulsified asphalt is sometimes used for damp-proofing purposes. Its particular advantage is its direct adherence to damp walls. It has distinct shrinkage tendencies, but such shrinkage is not objectionable in places where the wall is accessible so that the application of the emulsion can be repeated when defects appear.

3. FURRING

The use of furring must be approved or rejected by a consideration of the protection required against condensation. It serves principally as an insulating medium. The cold on the exterior of a wall may cool the interior face below the dew-point of the air in the building, in which case moisture condenses on the inside face. If furring is used, the wall masonry approaches more nearly the temperature of the outside air, and the furred-out plaster approaches more nearly the temperature of the inside air, establishing a condition which reduces the danger of cooling the plaster below the dew-point. If furring is used, the air spaces, preferably, should run horizontally rather than vertically, as this arrangement reduces air circulation and the heat loss caused by convection.

The Bureau of Standards, in their research on the subject of wall plaster, completed in 1923, strongly recommend the use of furring for exterior walls. They recommend that tile furring be bonded to the wall by metal ties spaced two feet vertically and three feet horizontally, with no plaster bond between the furring and the masonry wall. The mortar recommended for use with terra cotta tile is a 1–1–6 mix; and for use with gypsum furring tile, one bag of neat gypsum plaster to two cubic feet of sand.

There can be no doubt of the effectiveness of furring in improving the durability of the plaster and the interior decoration, as well as in increasing comfort in the occupancy of the building.

For the best class of construction, and to avoid piercing the damp-proofing mastic or damp-proofing paint by wall ties, the use of standard partition tile in a free-standing partition just inside the masonry wall is sometimes preferred.

Less expensive furrings which provide equally satisfactory insulation from condensation are wood strips, with or without metal covering, depending upon the requirements of the fire codes. These strips, lathed with wood or metal, may be plastered or plaster board may be applied directly to the furring strips.

One of the strong arguments against the use of furring is that it occupies usable floor space. This fact becomes particularly important in skyscraper construction, where the office rents are based closely on area, and the rent per square foot is relatively high.

Apart from the question of condensation, which has no relation to moisture penetration from the outside of the wall, furring is not a necessity.

There is an apparent paradox in the behavior of the moisture content in a wall, which may prove of interest. Laboratory experiments have confirmed the fact that the moisture in a wall moves away from rather than toward the heated surface. This phenomenon is favorable for the rapid drying of exterior walls in heated buildings during the winter season. This principle accounts in part for the appearance of moisture on the interior of intermittently heated buildings, such as churches, and also for a condition observed in tropical countries where extremely high temperatures follow immediately after a continued wet season. In these cases, the walls become well saturated with moisture. With a high temperature on the outside of the building, and a cool interior, the principal part of the drying-out process must be from the interior, since the greater part of the moisture is driven to this surface. Such a condition causes a damp and unsanitary interior, the only remedy for which lies in adequately damp-proofing the inside face of the wall. This phenomenon of moisture movement away from the warmer side of a wall may possibly be explained by the reduction in surface tension of water at increased temperatures, or, possibly, by the expansion of air enclosed in the capillary tubes of the wall masonry on the warmer side of the wall.

V. Treatment of Wall at Floor Levels

At locations where the thickness of the typical wall is reduced to accommodate floor framing, which, in skeleton construction, is the structural support of the curtain wall, it is desirable to flash the brickwork to prevent water which may have collected in the masonry above from passing into the floor system or wall construction below.

An asphalt-impregnated fabric is used to considerable extent for this purpose, and gives satisfactory results. As in the case of mastic damp-proofing, this spandrel waterproofing fabric is not manufactured to a definite specification, but is sold on a trade-name basis. Accordingly, the reputation of the manufacturer and general opinion as to the product must guide in the choice of such a waterproofing.

VI. Parapets and Details at Juncture with Roof

Probably the most essential detail of parapet construction is the through flashing at the level of the roof cap flashing. This through flashing may be a continuation of the cap flashing. It serves as a cut-off against any water which may have penetrated the body of the parapet wall, and as a protection to the portions of the structure lying below. In the design of the through flashing, the main problem is the selection of a material or form which has an adequate natural bond with the mortar, or sufficient mechanical key so that a definite horizontal cleavage is not established in the parapet construction. Cleavage may not be considered a serious problem with low parapets, but, with parapets of greater height, it deserves increased attention. Roof flashing should always be carried up a sufficient height to provide freeboard above any water which may back up under snow and ice conditions.

For the better class of construction, through flashing under the coping is frequently used. Where such flashing is not specified, the details of the coping require careful attention.

It is sound practice to protect the inner face of the parapet from the weather. In high-grade construction this is usually done by means of metal sheathing. Such sheathing permits the inner face of the wall to breathe, and undoubtedly results in a drier wall. As an alternative, a damp-proofing mastic may be applied to the inner face of the parapet. This surface undergoes severe exposure, due to high and low temperatures, the direct action of the sun, and the wash of rainstorms. The failure of such mastic damp-proofing is often traceable to the lack of bond between the damp-proofing and the brickwork, caused by the absorption and retention of excessive moisture by poor mortar or underburned brick. It has been observed that mastic in this location occasionally shows a tendency to crack and to scale, and that gas pockets or water blisters frequently form. Under these conditions, the expansion caused by frost accelerates the breakdown of the waterproofing. Mastic damp-proofing has the advantage, however, of being fully accessible for maintenance and repair. Furthermore, such repairs can be made easily and effectively, as the new material bonds readily to the wall and to the original mastic.

The previous discussion of the characteristics of various mortars should be borne in mind in connection with parapet construction, as the damaging exposure conditions at this location materially reduce the chances for satisfactory lime mortar performance.

The exposed or outside face of parapet construction should not be given a waterproofing treatment, by reason of the principle previously discussed, namely, that no masonry wall should be sealed on both sides.

The considerations which control the selection of materials for the body of the wall apply equally to the choice of the masonry units for the parapet. It frequently happens that, because a parapet is outside the building, it is regarded as of secondary importance, and, therefore, a convenient place for the use of bricks which may have been rejected as being unsuitable for the exterior walls below. Because of the added exposure to which parapets are subjected, certainly no lower grade of workmanship or of materials should be permitted here than is considered acceptable for the body of the wall.

The futility of attempting to secure a water-tight roof deck over porches or small balconies through the use of cement or tile finish alone should be noted. Depending upon the areas involved, either a sheet-metal, or a built-up, roofing should be used under the cement or tile finish in all such locations, and this roofing should be turned up at parapets or balustrades, and adequately detailed in connection with a through cap flashing. Attention should be given to the complete flashing of the washes of pediments and dormers.

VII. Construction at Openings

Reference should be made to the details of construction for spandrel beams previously discussed. For window and door openings, lug sills are effective in protecting the body of the wall from moisture penetration. They should be detailed with the full depth of the sill projecting into the body of the wall and pitched to slope away from the jambs as well as from the sash or door. Flashing should always be provided under brick sills. Scuppers through parapets and through spandrel beams at floor levels must be adequately flashed, and provided with proper drips of sufficient size for their intended purpose.

An important detail of exterior wall construction is the caulking of openings and joints between materials. The joints may be those —

(*a*) between same materials exposed in a level bed to the action of weather, as in sills not of one piece; parapet copings; and projecting members, such as cornices, belt courses, etc., (*b*) between masonry and metal; or between masonry and wood, such as at window frames, door frames, etc., and

(*c*) at horizontal expansion joints at floor levels where masonry walls are supported on skeleton steel frames.

Where frames are required, their detail should provide space for the deposition of a caulking compound, and, preferably, they should have a removable staff bead.

A study of elastic caulking compounds has recently been made by H. H. Dutton at the United States Bureau of Standards. Approximately sixty samples of caulking materials were furnished by over thirty manufacturers. Only four of these compounds are outstanding as meeting the essential qualities of adhesiveness, elasticity and permanence.

VIII. Projecting Members

The previous discussions of caulking compounds and of relative volume change due to heat and moisture are particularly pertinent under this heading. Vertical jointings exposed to excessive moisture should be avoided wherever possible. Accordingly, window sills, door sills and chimney caps should preferably be of one piece.

Where concrete copings are used, the use of definite expansion joints approximately 20 feet on centers should be considered. The coping should be reinforced longitudinally, and building paper or other material should be provided to break the bond between the brickwork and the coping. An approved caulking compound should be used at the expansion joints. The above details apply when a through metal flashing is not used immediately under the coping, although even in this case, a short metal flashing under the joints is advisable. It may be broadly stated that approved caulking compounds should be used in all joints which occur in the horizontally exposed faces of masonry. Ordinarily, mortar will not function satisfactorily in such locations. Similar attention should be given to ornamental masonry railings or balustrades at balconies and at roof levels.

An adequate drip is an essential detail for all projecting members. The use of drips will do much toward keeping buildings clean and in giving added protection against the penetration of moisture through the exterior wall. It is difficult to corbel out satisfactorily with masonry units, unless the projecting courses are amply protected against moisture penetration. Where an attempt is made to reduce pilasters to the normal wall line by stepping back the brickwork, the liability of moisture penetration is increased several-fold. Such pilasters should be capped by single stones or by metal flashing. Care should be taken to avoid long vertical joints, as in soldier courses in brickwork, at the juncture of the body of the wall and architectural features, and at the joining of different materials such as at pilasters, stone trim around windows, and at the corners of buildings.

IX. Base or Ground Course

The portion of a wall at the ground level is subjected to more rigorous conditions than are the typical portions of an exterior wall. These conditions include contact with snow and ice for long periods, constant moisture during many freezing and thawing cycles, ground splash from storm water, and moisture absorbed from the damp ground due to the capillarity of the masonry. Such conditions are similar to those resulting locally from defective down-spouts, where the wall surfaces weather at a faster rate, due to wash and continued moisture during the winter season.

Where brickwork is specified for base or ground courses, the use of a straight cement mortar is preferred, because of the tendency of the lime content of a mixed mortar to leach out in the presence of moisture. The same is true, but to a less extent, of the mortar used in parapet construction.

It is better construction practice to avoid brick masonry at the ground level, and to use concrete, granite or one of the other more durable building stones. These ground courses should be selected and designed so as to present a minimum of jointing to the weather.

X. Other Facing Materials and Treatments

The subject of surface waterproofings has already been discussed in considerable detail. As a general rule, it may be stated that, if the exterior surface of a wall is treated, every effort should be exercised to make the surface absolutely waterproof; and that no wall should be waterproofed on both sides, unless it is ventilated through internal cavities.

The proper surface treatment of limestone will reduce the amount of dust and soot that tends to accumulate on the face of the wall, and the consequent staining in the presence of moisture. D. W. Kessler of the United States Bureau of Standards considers this subject in his study, "Exposure Tests on Colorless Waterproofing Materials." This treatment is essentially a waterproofing treatment, and dissolved paraffin seems to combine the largest number of desirable characteristics for this purpose. All these treatments darken the color of the natural stone during the early stages of exposure. It may be that, under certain circumstances, the improved cleanliness of limestone facing gained through the use of a surface waterproofing will be preferred rather than close adherence to the general principle of free breathing previously discussed.

The "Stucco Investigations" of the Bureau of Standards, concluded in 1926, probably present the best information on the use of stucco as a surface treatment for exterior walls. A detailed discussion of materials and workmanship pertaining to this method of treatment is not possible here. A recent edition of the "Plasterer's Manual," published by the Portland Cement Association in 1929, is worthy of mention in this connection. Professor Kreüger, in his "Investigations on Climatic Action on the Exterior of Buildings," has much to say in favor of a lime mortar stucco. He has demonstrated that the rate of evaporation from saturated lime plaster equals the rate from the free surface of water, under the same humidity, temperature, and air movement conditions. It appears that this type of construction is quite usual in Sweden. The best thought in this country is in favor of Portland cement stucco for all exposed surfaces requiring plaster.

The general principles previously discussed are directly applicable to the use of granite, limestone, marble and terra cotta as facing materials for exterior walls. With some of these materials, non-staining cements should be used. With limestone and marble, it is good practice to parget the unexposed faces.

Incident to the use of natural or artificial stone for the facing of buildings, particularly when the stone is used as a veneer, are the metal anchors, ties and brackets projecting from the backup materials for its support. Iron bars or wire, if not rust-proofed, must be made of sufficient size to retain adequate strength during the life of the building, after allowance has been made for progressive corrosion. The increased size of anchors, due to rusting, may damage the facing. On this account, the use of a non-corrosive metal, such as brass or copper, is preferable. Iron may be protected by galvanizing, sherardizing or udyliting. These methods are recommended, as the use of paint or cement mortar affords neither adequate nor permanent protection. Galvanizing may be used satisfactorily on members which do not require recutting of threads or reaming of holes. The udylite process consists of electroplating with cadmium, with a subsequent heat treatment. Rethreading is not necessary with this process or with sherardizing. Greater security from corrosion is claimed with udyliting than with either galvanizing or sherardizing, and anchors so treated are reported to be more economical than copper or brass anchors of equal strength.

XI. Maintenance

Excessive moisture induces disintegration. Much harm is done by the entry of storm water through imperfect flashings, through shrinkage or settlement cracks in the body of the wall, or at points where the bond between the masonry unit and the mortar has failed. Excessive moisture coming to the surface aggravates any tendency toward efflorescence which may exist. Maintenance, therefore, should be directed, first, toward the correction of imperfect wall flashings, and second, to the careful and prompt pointing of mortar joints which have failed or are badly weathered. Efflorescence may be removed by a wash of weak hydrochloric acid, the wall to be thoroughly flushed with clear water after the use of this acid wash.

OF GENERAL INTEREST

MEMOIRS

Oscar Holmes Tripp *

DIED AUGUST 24, 1927

OSCAR HOLMES TRIPP was born January 15, 1852, at Waterboro, Maine, the son of the Reverend Leander and Louisa A. Tripp. His father was a Baptist clergyman, and his early years are difficult to trace because of the migrations made necessary by this calling. His youth was spent in Hancock County, Maine, where he received his primary education in the public schools. He afterward attended one of the Maine academies and later studied law, being admitted to the Hancock County Bar, and subsequently practicing at Bluehill, Maine. As was not uncommon in the earlier days, he carried on the practice of surveying in conjunction with the practice of law; but gradually a keener interest in the problems of engineering drew him from the legal profession, and it was as an engineer that he was known.

From 1881 to 1884 Mr. Tripp was employed as assistant engineer on the Bangor & Katahdin Iron Works Railway, and the Bangor & Piscataquis Railroad. Both these roads are now part of the Bangor & Aroostook system. In 1885 he opened an office at Rockland, Maine, for the general practice of engineering, and except for occasional short engagements in other sections of Maine, and fifteen months of the years 1898 and 1899 spent as assistant engineer in the sewer department at Arlington, Massachusetts, he was located at Rockland. During this period he served for several terms as city engineer.

He was an assiduous reader, with a taste for literature and history as well as science. He was very observant, and this, coupled with the fact that he made a record of his observations and the happenings of the day, gradually made his office a treasure house of accurate information on local history.

Mr. Tripp was a member of the Knox County Bar Association, and for several years had served it most efficiently as treasurer and librarian. He was a member of the Congregational Church. He was a Scottish Rite and a York Rite Mason. He was also a member of the American Society of Civil Engineers.

He died suddenly of heart failure in the Houston-Tuttle Book Store in Rockland, while browsing, as was so often his custom, among the new books. For several years Mr. Tripp had been in ill health, and none realized as well as he how near death hovered. Nevertheless, he continued his work up to the day preceding his death. He was unmarried, and his nearest surviving relative is a niece, Mrs. Flora T. Cooper of Portland, Oregon.

Mr. Tripp was elected a Member of the Boston Society of Civil Engineers on June 20, 1894.

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* Memoir prepared by Walter C. Groves, Assoc. M. Am. Soc. C. E.

Austin Bradstreet Fletcher *

DIED MARCH 8, 1928

AUSTIN BRADSTREET FLETCHER was born at Cambridge, Massachusetts, on January 19, 1872. His father, Ruel H. Fletcher was, during a long and active life, a teacher in the public schools of Cambridge. His mother was Rebecca C. (Wyman) Fletcher. They were descendants of English stock, whose ancestors came to Massachusetts in early colonial times.

Mr. Fletcher prepared for Harvard University at the Cambridge High School, and entered the Lawrence Scientific School in the fall of 1889. After two years of work in the general science course, he took courses in civil engineering, and was graduated in 1893, receiving the degree of Bachelor of Science.

Immediately after his graduation from college he took a position as secretary with the newly organized State Highway Commission of Massachusetts, and remained in the employ of this commission until 1910. He had not been long in active work before he gave evidence of that exceptional executive and administrative ability for which he became noted. At the time he left the Massachusetts Highway Commission he was performing the duties of executive officer and chief engineer of the commission.

The State highway work in Massachusetts was pioneer work in this field, and attracted nation-wide attention, both for the actual work accomplished, as well as for the organization developed. Great credit was given Mr. Fletcher for the smooth running, efficient organization that he perfected, the personnel of which was maintained for more than twenty years. This alone presents a great contrast to the many changes which have so often characterized public works enterprises.

During the time he served the Massachusetts Highway Commission, this organization was given supervision over the long-distance telephone lines along the public highways, which in consequence greatly broadened the scope of his duties.

At this period the character of highway traffic was undergoing a great change. It was evident that the past methods of construction would be insufficient to withstand motor traffic. The great problem presented was how most economically to treat the roads already built, in which large sums had been invested, and also how best to build the new roads. No one foresaw these changes and the new demands better, or felt the responsibility more keenly, than did Mr. Fletcher. The many experiments and methods of treating road surfaces that were carried on by the Massachusetts Highway Commission attracted the widest attention. At the time Mr. Fletcher severed his connection with the commission he was established as the foremost engineer in the highway field.

In 1910 he was induced to accept the position of chief engineer of the Highway Commission of San Diego County, California, where a construction program involving millions of dollars was planned. He was engaged in this work scarcely a year when he was appointed the first State Highway Engineer of California. Here he was destined to accomplish the greatest and most comprehensive program that has fallen to the lot of any highway engineer. One of Mr. Fletcher's colleagues in this work pays the following well-deserved tribute:

> So well did he install system in California that few changes have been made, or perhaps can be made, in the engineering principles and standards devised by this far-seeing pioneer of

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* Memoir prepared by A. N. Johnson, M. Am. Soc. C. E.

highway development. His ideas and ideals will ever remain foundation stones of the organization structure of the State Highway Department of California.

While engaged as State Highway Engineer of California, Mr. Fletcher was called in consultation, on several occasions, by the United States Bureau of Public Roads. During the summer of 1916 he assisted in drafting the rules and regulations to carry into effect the Federal Aid Road Law, which had just been passed by Congress.

Following the death, in 1918, of Logan Waller Page, M. Am. Soc. C. E., chief of the United States Bureau of Public Roads, Secretary Houston, of the Department of Agriculture, tendered this position to Mr. Fletcher, who declined it, preferring to carry on the great road program in California in which he was engaged.

From 1917 to 1923, in addition to his highway duties, he was president of the California State Reclamation Board, and from 1921 to 1923 he was director of Public Works of California. In January, 1923, he was called East to act as consulting engineer for the New England Rail Committee. This committee was made up of representatives of six New England States to study the whole transportation system in New England. Mr. Fletcher made a study and submitted a report on the motor-truck transportation phase of this investigation.

From September 1, 1923, until his death, Mr. Fletcher was connected with the United States Bureau of Public Roads as consulting highway engineer.

In 1908 he was sent, as delegate from Massachusetts, to the First International Road Congress, held in Paris, France. He attended the Third International Road Congress held in London, England, in 1913, as delegate from California. In 1914 he was chosen president of the American Road Congress, which was held at Atlanta, Georgia, in November of that year. During the World War he was a member of the executive committee of the California Council of Defense.

He was the author of a bulletin on "Macadam Roads" issued by the United States Department of Agriculture in 1906. He contributed the chapter on "Drainage" in the "American Highway Engineer's Handbook," and published many papers in various technical journals.

Mr. Fletcher was a member of the American Society of Civil Engineers, American Society for Testing Materials, the American Association of Engineers, the American Concrete Institute, the Massachusetts Highway Association, the American Road Builders' Association, the American Association of State Highway Officials, the Permanent International Association of Road Congresses, and a Fellow of the American Geographic Society.

He took a great interest in and was a member of a number of historical and patriotic societies, among which were the New England Historic Genealogical Society, the Massachusetts Society of Sons of the American Revolution, and the Society of the Colonial Wars of California. He was a member of the Cosmos Club of Washington, D. C., of the Harvard Club of San Francisco, California, and of the Harvard Engineers Club of New York City.

Mr. Fletcher died on March 8, 1928, at his home in Chevy Chase, Maryland. He had just returned from a business trip to Cleveland, Ohio, where he contracted a severe cold that developed into pneumonia.

On March 1, 1894, he was married to Ethel Hovey of Cambridge. There were two children, Dorothy, now Mrs. Laurence H. Chapman of Sacramento, California, and Norman, who died when but seven years of age.

Although Mr. Fletcher was shy, sensitive and modest to a fault, he was, nevertheless, an exacting and firm administrator. He wasted little time on what he considered useless argument and speculation; he was not to be stampeded. He had that essential quality of all great executives, — the ability to select a capable personnel, and to inspire and maintain in his organization that spirit of loyalty and enthusiasm aptly called *esprit de corps*. While he was severely just in his dealings with subordinates, his disciplinary measures were always tempered with a kindliness that left no heart-burnings.

Those of the organization which he perfected in California speak of him with the greatest respect and loyalty. In the April, 1928, number of the "Official Journal of the Department of Public Works of California," dedicated to him, there is paid this testimonial to his all too short but useful life:

> Mr. Fletcher lived to see the tree of his life mature and fruit in an added happiness and an enlarged usefulness given to the whole people of California. What greater monument could any one build? What greater reward could any one ask?

Mr. Fletcher was elected a member of the Boston Society of Civil Engineers on March 21, 1894.

Hezekiah Bissell *

DIED JUNE 23, 1928

HEZEKIAH BISSELL was born at East Windsor (Scantic), Connecticut, on February 7, 1835, the son of John Bissell and Elizabeth (Thompson) Bissell. He was a direct descendant of John Bissell who settled in Windsor, Connecticut, in 1639, and a year later removed to the east side of the Connecticut River.

Mr. Bissell attended the schools of East Windsor and Williston Academy at Easthampton, Massachusetts, where he prepared for college. He entered Sheffield School at Yale University in 1857, but three months before his graduation in 1861 he left school and enlisted at Hartford, Connecticut, in Company A of the First Regiment, Connecticut Volunteers. He was one of the first to answer the call for the three months' volunteer service, enlisting on April 18, 1861, serving his term of ninety days, and being mustered out on July 31, 1861. On August 23, 1862, he re-enlisted in Company G, 25th Connecticut Volunteers, and was chosen first lieutenant of that company, which was largely made up of volunteers from his home town of East Windsor and the neighboring towns of South Windsor and Glastonbury, Connecticut.

This regiment served with General Banks in the Louisiana Campaign, and was engaged in the siege of Port Hudson and the Battle of Bayou Teche. Mr. Bissell's second service being a nine months' enlistment, he served his full time, and was mustered out on August 26, 1863, so that his complete service was for nearly sixteen months.

With the other students of Yale who left college to enter the army in 1861, he was given the degree of Bachelor of Philosophy in 1881.

As an example of Mr. Bissell's oneness of purpose the following is taken from his personal memoirs:

> When a pupil in Williston he was asked by Mr. J. M. Stoughton, an old friend of his father, what he intended to do, and his reply was, "I am going to help build the Pacific Railroad; then

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* Memoir prepared by Lester W. Tucker, M. Am. Soc. C. E., M. B. S. C. E., and Walter H. Norris, Assoc. M. Am. Soc. C. E.

go to South America to build more railroads; then for my real life work be engineer of some first-class railroad in the United States; later, I will invent something to give me all the money I want to enjoy life."

And in his personal memoirs, written after his retirement from all business, Mr. Bissell adds this statement: "I have done all but the last of these."

Soon after his discharge from the army Mr. Bissell went to New York City, and at the office of the Union Pacific Railroad Company in that city met the late Thomas C. Durant, F. Am. Soc. C. E., president, and Peter A. Dey, chief engineer, of the proposed railroad. As a result of this interview he was appointed second assistant engineer by Gen. John A. Dix, and on April 1, 1864, reported at that company's office at Omaha, Nebraska. From this date until its completion on May 10, 1869, he was engaged on some part of the great undertaking.

His positions on this work were that of second assistant engineer, first assistant engineer, division engineer, and resident engineer, but in the latter part of his service much of his time was spent in special assignments on various important undertakings. As locating engineer, Mr. Bissell located and built much of the original line from Laramie, Wyoming, to west of Green River, and he was one of the party who ran the preliminary trial lines from the south end of Great Salt Lake westerly into what was then called the Great American Desert, and, with this party, endured great hardship. He was the only engineer who stayed with the undertaking from the beginning of the work to its completion, a period of more than five and one-half years. In his own words he had "staked out the first culvert at Omaha and was present when the gold spike was driven at Promontory Point."

In 1901 Mr. Bissell, while on a trip to the West, stopped at Omaha and met Mr. Burt, then president of the Union Pacific Railroad Company. Mr. Burt invited him to ride over the road with which he had been so intimately connected thirty-five years before, furnishing him a car and the division engineer as escort, and arranging for the entire trip to be made by daylight.

Again, in 1919, on the occasion of the fiftieth anniversary of the driving of the gold spike, Mr. Kennedy and Mr. Bissell were guests of the railroad company, and were the only representatives of the original engineering officials.

Mr. Bissell's work on the Union Pacific Railroad closed in June, 1869, and he returned East, but had been there only a short time when he was asked by Dr. Durant, the former president of the Union Pacific lines, to undertake the location of the Adirondack Railroad, then proposed to be run from Ogdensburg, via Canton, to Saratoga, New York. Surveys on this line were started late in August, 1869, and from that time until the fall of 1870 the work of surveying and grading was carried forward; but during 1871, money being scarce, little was done, and the work on this line was closed.

Early in February, 1872, he received an offer to go to South America on the roads then being built and projected by Mr. Henry Meiggs for the Peruvian government. He sailed from New York on May 15, 1872, and after a very stormy passage to Colon (then called Aspinwall), and a slow trip down the west coast, he finally landed at Mollendo, the port of Arequipa, Peru.

His work was that of locating and building the railroad from Juliaca, northerly up the Pucara River for a distance of about 100 miles, this being on what was projected as the main line from Puno, a port on Lake Titicaca, to Cuzco, the ancient Inca capital of Peru.

This section, being northerly of Lake Titicaca, was located on the backbone of the Andes, and was from 12,000 to 14,000 feet in elevation for its entire length.

The 100 miles were located and graded complete and ready for track, and Mr. Bissell was ordered to establish his camps and get ready for the location and grading of the remainder of the line into Cuzco, when he received sudden orders to stop all work and leave the country at once. A revolution of great intensity was under way in the northern districts of Peru, and all Americans had to flee.

Mr. Bissell was engaged for two years on this work, the entire period having been spent at these high altitudes with few, if any, white men, and at a time when it was necessary to live as the natives lived. He always thought that his thin hair and beard was one of the results of his mode of living during these two years.

Returning to his home from this work early in 1875, he received an offer to go with the Cleveland, Cincinnati, Chicago & St. Louis Railway Company, and for the next three years was with that road in various engineering capacities, revising locations, examining bridges, and constructing cut-offs from Cincinnati, Ohio, to the north and west.

On February 1, 1878, Mr. Bissell was appointed master of maintenance of way of the Eastern Railroad Company, extending from Boston, Massachusetts, to Portland, Maine, with headquarters at Salem, Massachusetts. The Eastern then had 270 miles of road. In 1884 it was taken over by the Boston & Maine Railroad Company, and Mr. Bissell was made chief engineer of the Boston & Maine lines, with headquarters at Boston. In 1886 the Boston & Lowell lines were taken over by the Boston & Maine, and in 1900 the Fitchburg lines came under the same management, so that Mr. Bissell became the chief engineer of one of the largest railroads in the East, with a mileage of 2,300.

While acting as chief engineer of the Boston & Maine system, Mr. Bissell had charge of the rebuilding of much of the roadbed, many of the bridges, and the greater number of the railroad stations on that line. He relocated many miles of the first road, double-tracked much of the original Eastern and Boston & Maine lines, and reduced grades and curves, eliminated grade crossings, and built many new yards, terminals, wharves and docks.

On June 30, 1909, Mr. Bissell resigned his position as chief engineer after having served thirty-one years, and in his announcement, President Tuttle retired him with the title of consulting engineer and paid him an exceptional compliment of appreciation for his long and faithful service. The following year he went to California, where he made his home in Altadena.

Mr. Bissell was a man of rare intelligence, great integrity, and oneness of purpose. He held the respect and loyalty of all those with whom he came in contact, whether they were the men of his own organization or those of the contractors and builders with whom he was so closely associated. His directness of purpose, absolute honesty, and ability to see the other fellow's point of view made engineers and contractors alike respect him and his decisions. He was especially kind and helpful to the young engineers of his organization.

Mr. Bissell was twice married. His first wife was Alice Hughes of St. Thomas, Ontario, Canada, to whom he was married in 1875 and by whom he had three sons, all living. His second wife, Segrid Johansen, to whom he was married in 1910, died several years later.

Mr. Bissell was a member of the Yale Engineering Association, American

Society of Civil Engineers, Southern California Association of Engineers, Engineers' and Architects' Association, and the Yale Alumni Association. During his long residence in Boston he was a member of many of the leading social and literary clubs of that city, but withdrew from most of these when he went to California. In his early manhood he was a member of the Congregational Church, but after his marriage he united with the Protestant Episcopal Church.

Mr. Bissell was elected a member of the Boston Society of Civil Engineers on March 21, 1883.

Fred B. Forbes *

DIED JANUARY 26, 1929

FRED BETTINSON FORBES, son of Andrew Jackson Forbes and Ella Bettinson Forbes, was born in Cambridge, Massachusetts, on January 30, 1872, and died in Somerville on January 26, 1929. He belonged to two old New England families, and was a member of the Massachusetts Society of the Sons of the American Revolution. He attended the Cambridge public schools, and was graduated from the Massachusetts Institute of Technology in 1893. He began his life work in July of that year as an assistant chemist of the State Board of Health of Massachusetts, at the Lawrence Experiment Station. In 1897 he was made first assistant in the State House laboratories. From that date until his death Mr. Forbes devoted himself unselfishly and faithfully to the work carried on in that laboratory, and so systematized it that probably no other laboratory of a like nature in this country turned out so much good analytical work at so low a cost. His particular forte was in overseeing his force and so arranging the work as to make the laboratory most efficient. He had little liking for research, preferring what might be called the business of laboratory operation, although considerable valuable work was done by him from time to time upon improving methods of analysis used in sanitary laboratories. Two or three papers on such subjects were written by him and published in chemical journals. In everything he did he was direct and concise, and he wasted neither time nor words. His mind was clear, and he knew how to express himself in good, clear, terse English. He could thus give information in regard to chemical questions and problems in plain, simple language easily understood by all. Throughout his entire life he never seemed to think of himself but of the work in hand and its value to the Department of Public Health and to the State. As recorded in the resolutions to his memory, passed by the State Health Council and published in the "Commonhealth" of January, 1929, "his service has throughout been marked by those qualities found only in a person of sound training, clear thinking, loyalty, conscientiousness and profound self-effacement."

Mr. Forbes was a man of great integrity, and, in the opinion of those who knew him and his work most intimately, no other chemist in the country could have carried on this work on a higher plane or with greater efficiency. The State of Massachusetts is fortunate to have had the services of so exceptional a man for so many years.

Besides his widow, who was Anna Maud Soule of Cambridge, and two sons, he is survived by his mother and three sisters, all of Somerville.

Mr. Forbes became a member of the Boston Society of Civil Engineers on March 16, 1904. He was also a member of the New England Water Works Association.

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* From the "Journal of the New England Water Works Association," June, 1929.

Fayette Samuel Curtis *

Died February 15, 1929

Fayette Samuel Curtis sprang from early American stock. Henry Curtis, his paternal ancestor, came from England in 1635, settling first at Watertown and then at Sudbury, Massachusetts. His mother's family also were early settlers of that State.

Fayette Samuel Curtis, the son of Allen and Catherine (Steel) Curtis, was born on December 16, 1843, at Owego, New York, and lived there for the first twenty years of his life, attending the district school until he was twelve, then private school for two more years, and, finally, Owego Academy, where he received special instruction in civil engineering.

Finishing with Owego Academy in 1863, Mr. Curtis was employed on the location and construction of a line for the Albany & Susquehanna Railroad Company, between Binghamton and Albany, New York, first as rodman, and then, in 1864, as transitman. Two years later he went with the Southern Central Railroad Company on its line from Owego to Auburn, New York, serving as levelman during the location, and then, with the commencement of construction, as assistant to the resident engineer. On the completion of this work he accepted a position as transitman with the Lake Ontario Shore Railroad Company, on location between Oswego and Charlotte, in New York State.

In the spring of 1869, as assistant to the late George S. Greene, Jr., M. Am. Soc. C. E., young Curtis was employed on surveys in the towns of Morrisania, Tremont and Fordham, now parts of Greater New York, which surveys have since served as the base of much of the later mapping in The Bronx. After two years of this work, in April, 1871, he returned to the railroads as assistant engineer, under the late I. C. Buckhout, M. Am. Soc. C. E., on the New York & Harlem Railroad, and six months later, on October 1, he became principal assistant, first, on the location of the tracks and yards at the old Grand Central Station in New York City, and later, on the plans and the construction of the Fourth Avenue Improvement between the Grand Central Station and the Harlem River.

On the retirement of Mr. Buckhout in 1874, Mr. Curtis became chief engineer of the Harlem Railroad Company and superintending engineer of the Fourth Avenue Improvement, continuing in the service of the former company until the completion of its line. The Harlem Railroad about this time was leased to the New York Central & Hudson River Railroad Company, and while Mr. Curtis was still acting as engineer for the Harlem lines, the grain elevators, yards, docks, piers, sheds and warehouses on the Hudson River, between Fifty-ninth and Seventy-second streets, were designed and built for the New York Central under his direction.

On December 1, 1882, Mr. Curtis was called to the New York, New Haven, & Hartford Railroad Company as chief engineer, with headquarters, first, at New York, and later at New Haven, Connecticut. This position he held until May 1, 1900, when he became fourth vice-president in charge of "engineering and such other matters" as might be assigned to him by the president or the board of directors, his headquarters being at Boston, Massachusetts.

As of June 1, 1903, his duties were more specifically set out as follows:

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* Memoir prepared by Clarence Blakeslee, M. Am. Soc. C. E., assisted by E. J. Beugler, C. C. Elwell, Edward Gagel, H. C. Keith, H. L. Ripley, Henry B. Seaman, Paul Sterling, and E. W. Wiggin, Members, Am. Soc. C. E.

"General supervision of the engineering department and construction, including the electrical department, except operation, also maintenance of way, and construction and maintenance of buildings and signals, except the operation of signals." This assignment remained unchanged when, on November 14, 1903, Mr. Curtis was made second vice-president, with headquarters at Boston, and also when, a year later, he was transferred to New Haven. As of October 1, 1905, however, he returned to Boston, to "represent the president with full authority in all matters requiring his attention," and remained in this position for two years. On April 1, 1907, he resigned the vice-presidency of the New York, New Haven & Hartford Railroad Company to accept the presidency of the Old Colony Railroad Company, which latter position, together with those of president of the Union Freight Railroad Company cf Boston, and chairman of the Boston Terminal Company, he held at the time of his death.

Mr. Curtis came to the New York, New Haven & Hartford Railroad Company very largely through the influence of Mr. Charles P. Clark, then second vice-president, who already had well in mind plans for a unified transportation system for southern New England, and who correctly appraised the worth of Mr. Curtis as an assistant in the development. The latter had but just come to the property, however, when Mr. Clark accepted a position with the New England Railroad Company, and the next four years in the engineering affairs of the New York, New Haven & Hartford Railroad Company were marked merely by consistent rather than by extensive improvements.

In the spring of 1887, however, Mr. Clark returned to the New York, New Haven & Hartford Railroad Company as president, and immediately began to build up and to expand the property. In this work Mr. Curtis played a most important part as one of the group of trusted lieutenants who served not only in the fields specifically assigned to them, but as general advisers and assistants as well. How highly his judgment was esteemed is shown by an endorsement on a letter in the office files of the company. President Clark had referred an inquiry to Mr. William E. Barnett, then executive secretary and attorney, who returned it with the note: "I do not know. Ask F. S.; he has second sight if any one has."

In December, 1882, when Mr. Curtis came to the New York, New Haven & Hartford Railroad Company, the line had double track from New York to Springfield, Massachusetts, approximately 123 miles, and single track elsewhere, the total single-track equivalent being but a little more than 400 miles. This was laid with 60-pound, or lighter, rail, most of the latter being iron. The great majority of its highway crossings were at grade, and in the year ending September 30, 1882, it had operated in round figures 185,000,000 passenger miles and had moved 117,000,000 ton miles of freight.

By 1907 the line from New York to New Haven had been completely four-tracked, as had that part of the Providence division from Readville into Boston, so that at the close of 1907, — when Mr. Curtis's assignment to Boston as "representative of the president, with full authority in all matters requiring his attention," made it desirable to relieve him of close control of engineering, — there were being operated about 4,254 single-track equivalent miles with 89⅔ miles of line four-tracked and 651¾ more, double-tracked, largely laid with 100-pound rail on stone ballast. The section of this rail was designed by Mr. Curtis in 1893, its height of 6 inches, with a 6-inch base, giving extra stiffness and stability. There was not a single grade crossing on the four-track sections, from New York to New Haven, and that in the vicinity of Boston, and a large number elsewhere on the system had been eliminated, notably in connection with very extensive improvements at Westerly and Providence, Rhode Island, Hartford, Connecticut, and Attleboro, Brockton, Fall River and Worcester, Massachusetts; while the traffic had so increased that in 1907 there were operated, roundly, 1,256,000,000 passenger miles, and 1,889,000,000 ton miles of freight were moved.

This, however, is but the merest outline of the story of railway improvements for which Mr. Curtis largely was responsible. With much of the work in thickly settled communities, and all of it adjacent to, if not directly under, heavy traffic, engineering ability of the highest quality was demanded, both of the chief and of his assistants. How well the test was met by Mr. Curtis's professional skill and the keen discernment with which he picked his lieutenants, is clearly shown in the fact that in the conduct of this great work not a single passenger was killed or seriously injured; and this record was practically duplicated as regarded the general public, except as to accidents resulting from the personal carelessness and disregard by the injured persons of barriers and warnings.

Nor is it without significance that, except as in some instances prospective increased loadings far above those for which they were designed have necessitated the replacement of some of the earlier structures, there have been neither failures nor indications of weakness in any of the structural work. This required that every contractor be held rigorously to his agreed performance; but it is quite characteristic of the fairness with which Mr. Curtis maintained his standards that in not a single instance was there an appeal to higher authority, either within the company or without, relative to his decisions.

Carrying to an extreme his dislike for any publicity, there is on record very little regarding the engineering features of this work thus broadly outlined. To the engineer familiar with New England conditions, however, the bridges, particularly over the tidal estuaries and the larger rivers; the elevated work through Bridgeport, Connecticut, Attleboro, Brockton, and the approach to Boston; the "cuts" at Mount Vernon, New York, New Haven, and in Boston; the stations at Bridgeport, Hartford and Providence, as well as many less important, all tell unmistakably of the hand of the master engineer.

Mr. Curtis also played an important part in the design of the South Station, Boston. He, with L. B. Bidwell, chief engineer of the New York and New England lines, and Walter Shepard, chief engineer of the Boston & Albany Railroad Company, representing the three roads for which the station was built, constituted the Consulting Engineering Board for that project. In 1895 Mr. Curtis accompanied President Clark and a party of officers of the New York, New Haven & Hartford Railroad Company to the Fifth International Railway Congress in London, England. At the close of the Congress he, Mr. Bidwell and Mr. Shepard visited the more important railroad stations of England and the Continent, studying their operation, their advantages, and their shortcomings, later employing the knowledge thus secured to the great advantage of Boston.

"F. S.," as he was very generally called, was a man of tremendous energy and splendid constitution. Up to less than a year before his death the average man of sixty-five would have found it very difficult to keep up with him. This was the more remarkable because he had never spared himself. His "day" ended when the work permitted, without reference to the time, and during the lifetime of Mr. Clark a long, active day in the field or office frequently was followed by conference until early morning with his equally tireless president.

Possessed of a kindly disposition and a keen sense of humor, Mr. Curtis had the happy faculty of making and keeping friends. His consideration of, and advice to, the young engineers who came under his direction were such as to inspire them to high ideals of engineering accomplishment, and there are many one-time associates who owe their later successes to his early training. With all his duties and responsibilities he always found a minute in which to greet even casual acquaintances, and to exchange the latest stories, his hearty and contagious laugh telling his keen enjoyment of a good tale. He was very fond of horses, and was a regular patron of the old Morris Park Race Track, taking unusual pleasure in attending the races with a crowd of his particular cronies.

He was a member of the American Society of Civil Engineers. He was also a member of the Connecticut Society of Civil Engineers, which he had joined on January 9, 1900, and of which he was made an honorary member on February 19, 1924.

Socially, he was a member of the Beacon Society, the Boston Athletic Association, and the Engineers Club of New York. His membership in the Quinnipiack Club of New Haven, which he had long held, he resigned about a year before his death.

Fraternally, Mr. Curtis was a prominent Mason, holding membership in Friendship Lodge, Harlem, in Jerusalem Chapter of Tioga County, and in Constantine Commandery, Knights Templars — all in New York State.

On October 19, 1872, he was married to Mary J. Bishop of New Haven, who survives him, as does a sister, Kate S. Curtis of Owego, and a half brother, Robert Curtis of New York. Of his three children — Wallace, George Henry and Mary J. — only the latter, who is the wife of Capt. John D. Woodworth, Medical Corps, U. S. A., at Vancouver, Washington, is now living. There are, however, five grandchildren: John Fayette, son of Wallace; George Henry and Dorothy M., children of George; and Fayette Curtis and Mary Justin, children of Mrs. Woodworth. Mr. Curtis's death, after an illness of three months, occurred on February 15, 1929, at his home in Jamaica Plain, Boston.

An engineer and executive of outstanding knowledge and ability, an indefatigable worker, a staunch and loyal friend, and a gentleman, his death is a great loss to his friends, to his profession, and to all who had the privilege of being associated with him or knowing him.

Mr. Curtis was elected a member of the Boston Society of Civil Engineers on February 17, 1915.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

Boston Society of Civil Engineers

FEBRUARY 17, 1932. — A regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, and was called to order at 7.15 P.M. by the President, Harry E. Sawtell. This meeting was the annual joint meeting with the following student engineering societies: Northeastern University Section of the Boston Society of Civil Engineers and Student Chapters of Harvard Engineering School, Massachusetts Institute of Technology and Tufts College.

About 330 members and guests were present at the meeting and 300 attended the buffet supper and smoker preceding it. During the supper music was provided by representatives of the musical clubs of Northeastern University, under the direction of their leader, Mr. B. F. White.

The President expressed the appreciation of the Society for the co-operation of the officers of the student engineering groups and of the faculty members who have interested the students in this meeting.

The Secretary announced that the following had been elected to membership by the Board of Government on February 17, 1932:

Grade of Junior: Carl Lawrence Mork, Frank Venti, Edward Frederick Wilcox.

The President called on Past-President L. E. Moore to outline the features of the proposed grade of student member in the Boston Society of Civil Engineers.

The President then introduced Mr. Raymond W. Coburn, Construction Engineer, Massachusetts Department of Public Works, who gave a talk on "Recent Developments in the Design and Construction of Highways." This paper dealt with the outstanding recent developments, including the Boston and Worcester Turnpike, elimination of railroad and highway grade crossings, traffic circles, by-pass routes, design, non-skid surfaces, low cost of secondary roads, concrete construction, treatment of swamps, modern machinery and bid prices.

Mr. George H. Delano, Maintenance Engineer, Massachusetts Department of Public Works, gave a talk on the "Recent Developments in the Use and Maintenance of Highways." This paper dealt with the increased activities which are now necessary features in the maintenance of highways, including surface, drainage, roadsides, traffic studies and control, safety measures, direction signs, traffic control signs and signals, and snow removal.

These papers were illustrated by lantern slides and motion pictures. Following each of these talks there were a number of questions presented.

Meeting adjourned at 9.45 P.M.

EVERETT N. HUTCHINS, *Secretary.*

DEATHS

LUKE D. MULLEN . .	Jan. 7, 1932
EDWIN H. ROGERS . .	Mar. 6, 1932

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FOUNDED 1848

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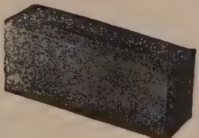

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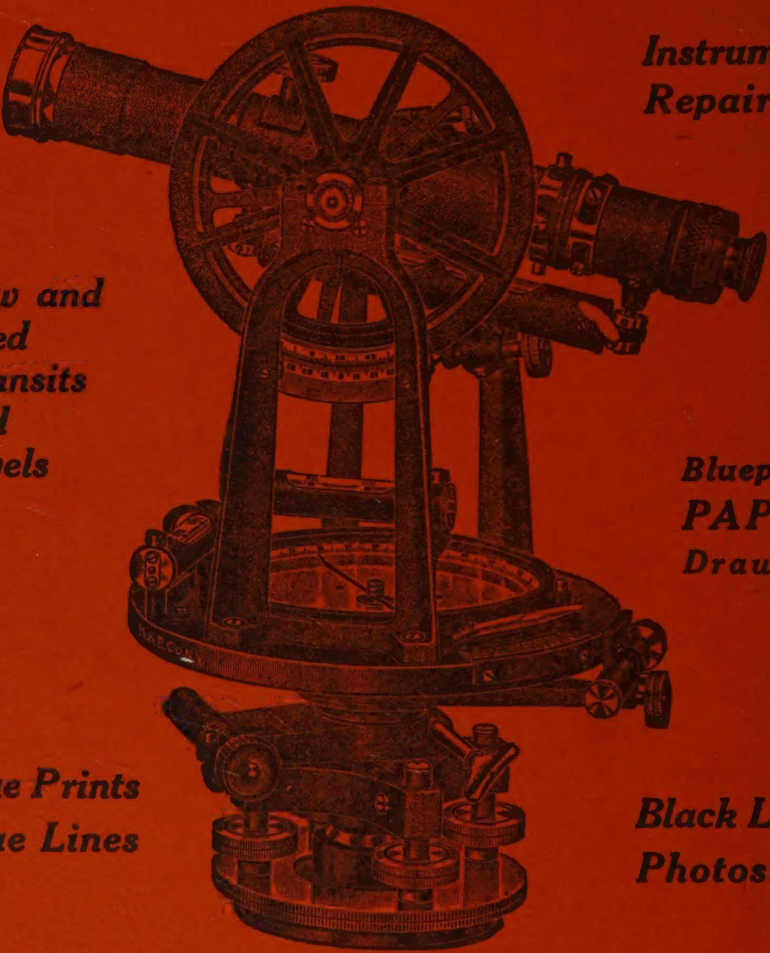

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